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January 11, 2010

Via Electronic Filing

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: ET Docket No. 03-104 and ET Docket No. 04-37; Broadband over Power Line Systems; Written *Ex Parte* Submission of ARRL, the national association for Amateur Radio

Dear Ms. Dortch:

On behalf of ARRL, the national association for Amateur Radio, formally known as the American Radio Relay League, Incorporated (ARRL), the following is submitted as a written *ex parte* communication, in response to that filed in this proceeding on or about December 30, 2009 by Current Technologies, LLC (Current).

Current submitted a "supplement to the record" which contained numerous inaccuracies, to which ARRL is constrained to respond. This response will address Current's assertions in the order in which Current raised them in its December 30 *ex parte* filing.

I. The Extrapolation Factor.

Current first claims that the (few remaining) BPL providers urge retention of the 40 dB/decade of distance signal decay extrapolation factor presently used in the Commission's rules, and ARRL supports a 20 dB/decade of distance extrapolation factor. The Commission, Current states, "proposed a Solomonic compromise" at 30 dB/decade, which Current claims both sides reject. Therefore, Current argues, the Commission is faced with a choice between polar opposites and "must pick 20 or 40 dB/decade." It then goes on to attempt to justify 40 dB/decade.

Current mischaracterizes ARRL's position on the extrapolation factor. ARRL has established that 20 dB/decade of distance is an appropriate extrapolation factor, to the extent that a single number is to be adopted by the Commission for all distances from the emitter at all frequencies usable by BPL systems. However, ARRL did note, based on authoritative technical publications and numerous widely accepted and used industry standards that it is correct to extrapolate at 40 dB/decade within a distance of wavelength (λ) over 2π (but only within that distance). ARRL also argued that the Commission should adopt a scientifically supportable extrapolation factor (provided that the ultimately appropriate and necessary rule change, requiring 35 dB notching on all amateur allocations, of which present BPL technology is clearly capable, is also incorporated in the rules). Although ARRL does not believe that 30 dB/decade is scientifically supportable as a single number across the board; it is more than a mere political or philosophical expediency, as Current has in effect labeled it; it represents a technical effort by the Commission staff to combine all the factors into a single number that is easy to use. The Commission is not, therefore, bound to adopt 20 or 40 dB per decade in order to "reach a result grounded in the record" as Current would have it.

The Court of Appeals, among other things, remanded the extrapolation factor to the Commission with specific instructions to either justify the 40 dB/decade factor or adopt a new one and justify it. Notwithstanding the Commission's protestations that 40 dB/decade was justifiable, it clearly was not, and the 30 dB/decade proposal in the Further Notice of Proposed Rule Making in this proceeding was an unequivocal (and at this point inevitable) acknowledgement by the Commission of the inappropriateness of the 40 dB/decade factor. That said, it is not incumbent on the Commission, as Current concludes, to adopt "either" 20 dB/decade or 40 dB/decade. Instead, it is incumbent on the Commission to adopt a *scientifically based and technically valid extrapolation factor*.

Current then proceeds to cite available studies which it claims "congregate more closely" toward 40 dB rather than 20 dB as the proper extrapolation factor. Again, however, Current is mistaken. The experimental evidence *does not* point to 40 dB/decade as the "preferred value" as Current asserts. The actual measurements in general point toward a value that, if averaged over a number of studies and averaged by frequency, is closer to 30 dB/decade than 40 dB/decade. Adding the most comprehensive of the actual test results, which is discussed in the attached paper entitled *Rationale for the Abandonment of the Use of a Single 40 dB/decade Extrapolation Factor for Radiated Emissions Measurements Made Below 30 MHz*, prepared by ARRL Laboratory Manager Ed Hare (Exhibit A), **the experimental evidence, authoritative texts and EMC industry standards strongly support a 20 dB/decade extrapolation factor**. ARRL is also attaching as Exhibit B a Field Test Report prepared by the Communications Research Centre Canada (CRC), an arm of Industry Canada, in March of 2009 which, based on extensive measurements, concludes that a signal decay factor of 18.2 dB per decade of distance is the proper extrapolation factor. This 18.2 dB/decade conclusion is an average of all of the measurements made that the front and back of sixteen buildings with wiring carrying BPL signals, on all frequencies from 2 to 30 MHz. This is deemed reliable by ARRL, and it is certainly a large enough group of measurements to warrant changing the rules. Though ARRL's technical submissions in this proceeding have been focused principally on overhead lines carrying BPL signals, the CRC study establishes that 40 dB/decade of distance below 30 MHz should be changed in Section 15.31 for <u>all</u> purposes, including in-premise and Access BPL. In general, ARRL is satisfied with its previous submissions on the extrapolation factor in this proceeding, but in view of

Current's December 30 *ex parte* submission, the attached exhibits are apparently needed to set the record straight.

Current's citation of other studies that it claims lean toward 40 dB/decade are unavailing. The NTIA Phase II study is, as ARRL has previously asserted, based on faulty premises. It is furthermore based on modeling and calculations, so calling it "experimental evidence" as Current does is hyperbole. The attached CRC measurements of 16 installations is of greater reliability and it clearly supports a 20 dB/decade factor.

Current cites the OFCOM (Winchester) study which exceeds 30 dB/decade over 1.5 to 9 MHz, and is otherwise lower, supporting the position that within $\lambda/2\pi$, decay with distance is higher than the 20 dB/decade that exists beyond that distance. As to Current's theoretical criticism of this test, that the test set-up has a BPL-equipped electric distribution line running parallel to the measurement path that may alter readings, the criticism is far-fetched. Current's premise is that competent technical people that conducted the test designed a competent test and prepared excellent test-result reports but failed to notice a nearby line carrying the signal that they were trying to measure. This is not a credible criticism, and Current's only source of that assumption is Current's view of a photo in that report. Without more, Current claims that the study should be discounted because another nearby power line *may* have been carrying BPL signals (from some unknown source).

Current next cites another of the OFCOM studies, in Crieff, Scotland, which it claims shows an extrapolation factor of 30-34 dB/decade in the range 10 to 30 meters. That of course provides no justification whatsoever for retaining a 40 dB/decade extrapolation factor.

Finally, Current claims that the CISPR 18 report is not relevant to BPL. As ARRL has previously explained, CISPR outlines limits and test methods that may not be specifically applicable to BPL, but BPL couples energy onto power lines in the same way that most noise sources do, so the description of the way that noise sources decay with distance from a power line is absolutely applicable to a determination of the correct extrapolation factor.

Current next asserts that BPL-equipped power lines do not radiate over their entire length, and claims that it has rebutted ARRL's assertion to the contrary with "supporting evidence from its own deployments, with which the Commission agrees." Actually, it is the Commission's own findings that demonstrate that power lines do indeed radiate along their length. It was for that reason, in part, that the Court of Appeals remanded this proceeding to the Commission for further review. The Commission's own findings clearly state that BPL is *not* a point source, though Current continues, incredibly, to assert that it is. The figures in the attached Exhibit A sufficiently rebut Current's argument.

The next assertion of Current reveals the depth of its conceptual misunderstanding of the physics of BPL radiated emissions. Current hypothesizes that in the event ARRL is correct, and that BPL radiates as a line source rather than as a point source, "[t]he large radiating element would would create a large near field. As a result, the extrapolation from any measurement distance out to the rated distance of 30 meters would take place entirely in the near field (footnote omitted). Due to the fast drop-off in the near field, an appropriate attenuation factor would be at least 40 dB/decade." Current therefore apparently believes that that the near field is defined solely by the dimensions of the antenna. In fact, however, it is the reactive near field, bounded by $\lambda/2\pi$, where the fields decay rapidly. In the "radiating near field", fields vary less rapidly overall, but develop standing waves that decay up and down with distance. The average power in this standing wave decays at 20 dB/decade. ARRL's filings in response to the Further Notice in this proceeding explain this, but there are other sources as well: See,

http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf08511.html#gl-2.2.2

The fundamental assumptions of Current in this respect are flawed, and its supposition does not lead to a conclusion that 40 dB/decade is the proper extrapolation factor, given that BPL power lines radiate as a line source.

Current's misunderstanding is further manifested in its next assumption: that ARRL is wrong, and that BPL radiates as a point source. It says, in that case, that "[t]he near field would then be small, and measurements would occur in the far field. *But the extrapolation factor for a point source, even in the far field, is (again) 40 dB/decade.*"(emphasis added). This is completely, and rather obviously, in error. For a point source or physically small radiator, there is only a reactive near-field region, which is bounded by $\lambda/2\pi$. Within that region, fields decay at approximately 1/D*D, or 40 dB/decade. Beyond that distance, fields decay at 1/D or 20 dB/decade.

For a non-point source, within $\lambda/2\pi$, fields decay at no more than 40 dB/decade, and for the magnetic field, for an infinite line emitter, they decay at 20 dB/decade right up to the source. Real emitters are somewhere between those extremes. Beyond $\lambda/2\pi$, fields decay up and down, out to a distance bounded by approximately 2D*D/wavelength, where D is the maximum size of the radiator. It is simply wrong to assume that there is only one "near field" and that it is defined only by the size of the emitter. Current's assertion drawn from that assumption, that fields decay at 40 dB/decade at any distance from a point source is a glaring error.

Current accuses ARRL of attempting to "have it both ways." To reach the 20 dB/decade result it "wants"[1], Current says, ARRL must assume "that 30 meters lies outside the near field of an extended radiating source. That is simply not possible at BPL frequencies." It goes on to note that the 40 dB extrapolation factor for frequencies below 30 MHz has been part of the rules for decades. Manufacturers, test laboratories, and

[1] Actually, ARRL doesn't "want" *anything* with respect to a particular extrapolation factor, except a valid scientific underpinning for the adopted extrapolation factor; there is not now and there never has been a scientific underpinning for the 40 dB/decade factor, even for point sources, as the Commission's own rules concede on their face. See, 47 C.F.R. § 15.31(f)(2). It was an assumption, and a placeholder for testing point-source radiators, and was never valid outside $\lambda/2\pi$.

TCBs are all accustomed to working with this value." There is nothing inconsistent about ARRL's explanation. Concisely restated, outside the $\lambda/2\pi$ region, theoretical considerations, industry standards and practical testing show that field strength varies at 20 dB/decade, on the whole, with standing waves. As to the comfort level of the industry with the 40 dB/decade number, the Commission's rules state that 40 dB/decade would be used below 30 MHz "pending the development of an appropriate measurement procedure for measurements performed below 30 MHz." The number of radiated emissions measurements below 30 MHz has been relatively small, and most of those have been well below 1 MHz. At frequencies below 1.59 MHz, both 10 and 30 meters are within $\lambda/2\pi$, so 40 dB/decade would be correct. Current's urging the Commission for "regulatory stability" in this extrapolation factor is, frankly, inappropriate, given that the Section 15.31(f)(2) rule describes the 40 dB/decade factor as a placeholder pending the development of a technically correct standard.

Current asserts that the same 40 dB/decade value is also used for in-home BPL measurements along the service wire leading to the home, and that the technical information in the record should be used for in-home measurements. Current asserts again that, absent a "compelling reason to change a rule, its long-standing presence on the books should weigh in its favor." Actually, the long-standing presence on the books of a standard that is specifically stated to be a temporary placeholder is in fact a compelling reason for the Commission to finally take some action adopt a scientifically based standard, not to retain the unsupported placeholder. As to the in-home BPL measurement argument of Current, the measurement of in-home BPL systems is done relative to the entire premise wiring, not just along the service wire leading to the home. The attached CRC study, Exhibit B, shows that the service wire does relatively little emitting. This report applies specifically to in-home BPL and it shows that, based on the results from 15 of the 16 homes measured, 20 dB/decade across all HF is correct and appropriate. Since there is no technological basis for differentiated testing of in-home BPL and access BPL, then the comprehensive CRC testing and study applies to both and 20 dB/decade is a correct value to apply.

II. BPL Interference and Existing Rules.

Current argues that the existing BPL rules are fine as-is because the Commission has sufficient experience with BPL. For this premise, it cites its own statistics: Current claims that it has "approximately 35,000 BPL devices"[2] operating in the United States. Current claims that this is a "respectable statistical sample" and asserts that it has received no interference reports. Therefore, it concludes that the rules are adequate as-is and are working as intended. Current also claims that it is unaware of any unresolved reports of interference "from any compliant device" since the rules were adopted.

[2] This is indeed a novel way to describe the extent of BPL deployments – by the number of pole modems in use. The less impressive, but more accurate way to explain Current's stake in BPL would be to list the number of BPL deployments throughout the United States.

This is a substantially deceptive argument. Current's BPL architecture takes interference avoidance steps that are not required by the Commission's BPL rules. Current's medium-voltage modems operate between approximately 32-48 MHz. They do not therefore utilize any Amateur allocation whatsoever. Their in-premise modems do operate in the high-frequency spectrum, but with notches in the am amateur allocations. Their notching depth is approximately 30 to 35 dB. Rather than justifying the retention of the existing BPL rules as-is, Current's BPL architecture and its argument (which ARRL concedes) that there are no unresolved interference complaints involving Current's deployed BPL systems, specifically and poignantly justifies a modification of the rules to require BPL systems to utilize the operating parameters that Current presently deploys.

Make no mistake: the present rules permit the deployment of BPL which causes severe, ongoing harmful interference if operated on spectrum that is in use locally, and there is ample, voluminous evidence of that in the record in this proceeding and in the Commission's files, including the conclusions of the Commission's own technical staff. The rules are completely inadequate as they stand to preclude harmful BPL interference to Amateur stations *ex ante*. The changes to the rules urged by ARRL: to require full time, mandatory notching of Amateur allocations at 35 dB notch depths, are both achievable by present BPL systems and are typically achieved by BPL. However, Current's argument, which in essence is that *we do something different from what the present rules require, but the present rules are adequate,* is a non-sequitur.

The inadequacy of the existing BPL rules is conceded in effect by John Joyce, the CEO of the Ambient Corporation, in an article published recently in a publication entitled "BPL International." Mr. Joyce noted, in relevant part, as follows:

> BPL does not perform well in the overhead U.S. electrical distribution topology, and thus today a BPL signal cannot communicate over long distances or through a transformer without couplers and repeaters to boost the signal. This additional equipment increases overall deployment costs and eliminates cost savings associated with using the existing wires. . . There are further problems in transmitting BPL signals over power lines, including interference issues caused and experienced by a BPL system. Overhead electrical distribution wires are unshielded from radio frequency (RF) interference, therefore, BPL signals traveling on medium-voltage overhead lines have the potential to interfere with shortwave radio operators. Local RF using unlicensed spectrum also can interfere with the BPL network signal, and because the spectrum is unlicensed, mitigation can be timely and costly.

Thus, though the remainder of Current's filing touts the potential of BPL (which is of no concern to ARRL, as long as the interference problem can be avoided by modification of the BPL rules), it is a "potential" that has never been realized to any significant degree. With many tens of millions of broadband lines available in the US, BPL has never enjoyed more than 0.011% of market penetration, and at each release of the newest FCC broadband report, that percentage has been smaller. Elimination of the interference potential of BPL, which most assuredly is one of the handicaps of the technology, cannot but help salvage whatever potential BPL may have in the future for broadband access, or for Smart Grid applications. Conversely, if Current is correct and there are Smart Grid applications for BPL, the interference potential of BPL must be addressed soon to avoid the fundamental incompatibility between BPL and the Amateur Radio Service that exists as the result of the present BPL rules.

Current is incorrect: the Commission most assuredly did not get the rules right the first time. The Commission's own technical staff proved that, and nothing in Current's filings or those of any other of the few remaining BPL advocates responding to the Further Notice offers any justification for retaining the 40 dB/decade extrapolation factor. The Commission is obligated, as ARRL has said many times, to adopt a scientifically valid distance extrapolation factor; no more and no less. The science dictates a factor closer to 20 dB/decade of distance than 40 dB. Nor is there any reason at all why the BPL rules should not be amended immediately to impose a mandatory, full-time, 35 dB notching requirement for all BPL modems in all Amateur allocations utilized. If that is done, the fundamental incompatibility is effectively eliminated, and BPL can, going forward, avoid the stigma of the spectrum polluter that it has been shown to be in deployments throughout the United States and elsewhere in the world.

Respectfully submitted,

Christopher D. Imlay
General Counsel, ARRL

Cc: Chairman Julius Genachowski
Commissioner Michael J. Copps
Commissioner Robert McDowell
Commissioner Mignon Clyburn
Commissioner Meredith Atwell Baker
Julius Knapp, Chief, Office of Engineering and Technology
Ira Keltz, Deputy Chief, Office of Engineering and Technology
Alan Stillwell, Deputy Chief, Office of Engineering and Technology
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Karen Ansari, Chief, Technical Rules Branch, Office of Engineering and Technology
Anh Wride, Senior Engineer, Policy and Rules Division, Office of Engineering and Technology
Mitchell Lazarus, Counsel for Current Technologies, LLC

Attachments
(Exhibits A and B)

EXHIBIT A

Rationale for the Abandonment of the Use of a Single 40 dB/decade Extrapolation Factor for Radiated Emissions Measurements Made Below 30 MHz

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Background

In response to the Further Notice of Proposed Rulemaking (FNPRM) in ET Docket 04-37, several commenters criticized ARRL's position that 20 dB/decade is an appropriate extrapolation factor to use irrespective of frequency. This paper summarizes information from a number of authoritative sources that provide the rationale and justification for ARRL's position. The paper also offers alternatives that consider the possible increased decay with distance, within a distance from radiating sources bounded by wavelength/2pi ($\lambda/2\pi$). Although these alternatives are a compromise of a number of technical factors, they are as flexible as possible, while still being reasonably consistent with the physics of electromagnetic (EM) radiation.

Near Field vs Far Field

Several entities provided comments that indicated that ARRL was not consistent in its positions relating to near field and far field radiation effects. Comments were also provided that identified overhead power lines as a point source, or a line source, in turn, depending on which entity within the BPL industry was providing the comment and in what context its position was being represented.

In reading those comments[1], it became apparent that those that provided them did not understand the nature of what happens to EM energy near physically small and physically large radiators, in free space and over conducting ground planes. In this paper, ARRL is providing additional information about the EM principles behind the differences between the reactive near-field regions and the radiating near-field/far-field boundary. This is not

[1] Perhaps the most egregious of these industry statements is found in an ex parte filing provided by Current Technologies, LLC on 30 December 2009 in which Current stated that the decay of field strength from a point source is 40 dB/decade *even in the far field* (emphasis added). It is clear from this misperception by Current that it does not understand the nature of electromagnetic-field (EM) radiation and the way that EM theory applies to radiating structures. This does explain Current's mistaken belief that ARRL's position with respect to near-field characteristics of power lines is inconsistent.

necessarily needed by the FCC engineering staff evaluating comments in this proceeding, but this information may helpful to others providing comments. Hopefully, they will focus more correctly on the complex electromagnetic and physics issues that need to be *correctly* expressed and considered in this proceeding.

Reactive near-field region

At points very near radiators, there is a near-field area called the reactive near-field region. In this region, electric (E) and magnetic fields (H) are not radiated in the classic sense of understanding that term. The radiator is creating E and H fields that are very strong in this region, but, much like what is seen in an inductor or capacitor, the power that is present is reactive. A layman's explanation of this is that in this region, the radiator is putting energy into the fields, but is taking it back. This region, very apparent in physically small radiators, but also applying to line emitters to some extent, is bounded fairly sharply at a distance of wavelength / 2pi ($\lambda/2\pi$).

Figure 1 below shows the boundaries of the various regions surrounding a radiating element.

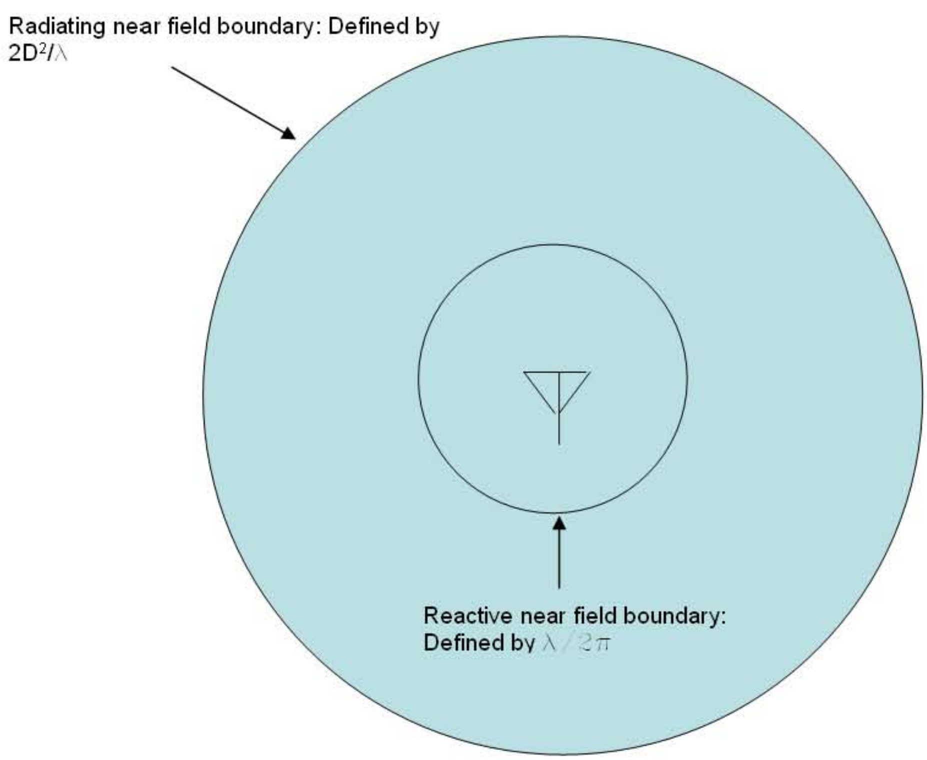

Figure1 – The area and size of the reactive near-field region is generally bounded by the size of the wavelength of the frequency of the emission, bounded by $\lambda/2\pi$. The area and size of the radiating near-field region is generally determined by the size of the radiating structure.

Figure 2 below shows the modeled radiated emissions[2] from a small electric dipole in free space. While free space is not entirely representative of all emissions from devices being tested for compliance with the FCC's emissions limits, it is a model best representative of the emissions at upward angles from all types of devices.

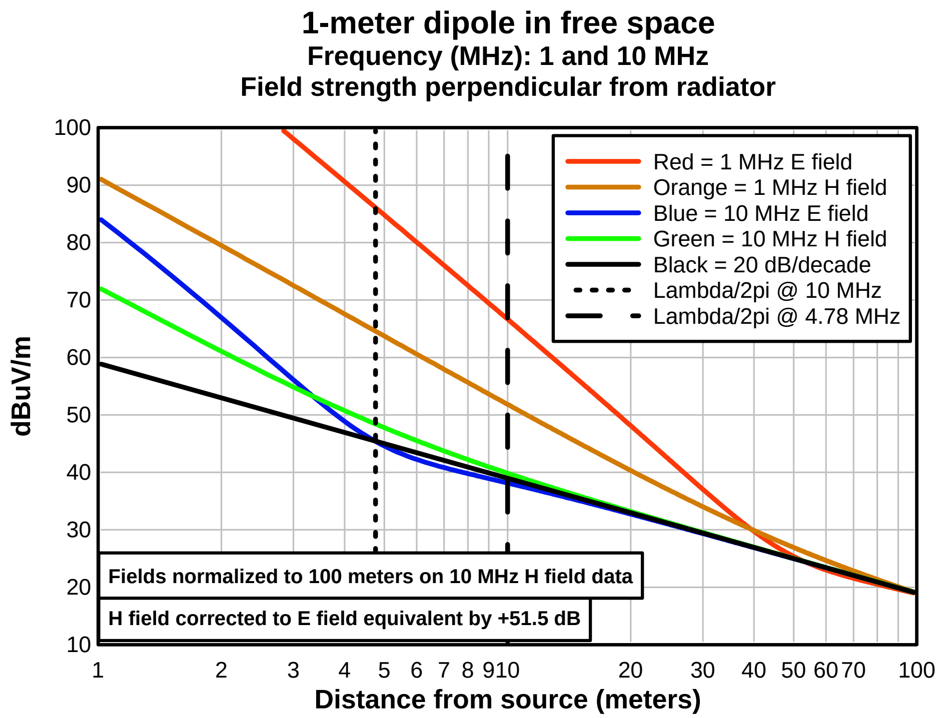

Figure 2 – This shows how E and H fields vary with distance from an electric-field point source. The delineation between the reactive near-field and far-field regions is most apparent in the E field, as would be expected from a small dipole, whose near field region is dominated by electric fields. This region is delineated by the classic $\lambda/2\pi$ definition. The E field dominates in the radiated emissions from a small dipole. If the emitter were a small magnetic dipole, the H field would dominate, with a decay rate that is 40 dB/decade within the reactive near-field region bounded by $\lambda/2\pi$.

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[2] The graphs in this document showing field strength near various radiators were developed using EZNEC Pro (http://www.eznec.com) using the NEC2 or NEC4 calculating engine. This software is a well accepted method-of-moments EM modeling tool. Modeling is used to show trends that are useful to setting test methods and extrapolation, especially of those trends are shown to be consistent across a number of different modeled assumptions.

Standards for Radiated Emissions Require Height Scan to Find the Point of Maximum Emissions

Any kind of emitter above any kind of ground surface will emit its field-strength maxima upwards[3] . This principle is demonstrated in ANSI-IEEE C63.4, an American standard incorporated into the FCC rules by reference. Radiated emissions tests require the receiving antenna to scan from 1 to 4 meters in height in order to detect the maximum emissions from the EUT. The European companion document, CISPR 16-2, requires the same 1-4m vertical scan for 10m limits, ***and a 2-6m vertical scan for 30m limits,*** such as those in the US for BPL systems operating under 30MHz. In the case of most emitters, this results in measurements being made above the radiating emitter. This is not practical or safe in the case of overhead power-line emitters, so this paper indicates alternative considerations that permit measurements to be made safely at a height of 1 meter and extrapolated in a way that best characterizes the way that EM fields behave near a wide variety of radiating structures.

Near-Field Boundary

There are a number of things that can be learned from analyzing the simple model shown in Figure 2. For physically small radiators (point sources), the near-field region is fairly sharply and clearly bounded by a distance of $\lambda/2\pi$. In this case, a small dipole was used, in which the E field dominates within the near-field region. If a small loop source were used for the model instead, within the near-field region, the H field would dominate. However, for physically small sources, most extrapolations of measurements will be made from a distance of approximately 10 meters to a 30 meter distance. **Above 4.77 MHz, distances of 10 meters and 30 meters are both in the far field region, where a 20 dB/decade extrapolation would be correct *for all points beyond 10 meters distance for point sources.***

Thus, for physically small sources, such as pad mounted transformers and premises with wiring carrying BPL signals, for examples, if measurements are made at 10 meters distance, over most of the frequency range, an extrapolation of 20 dB/decade would be exact to obtain an estimate of the field strength at 30 meters distance[4].

This small-source model is applicable to this discussion in a number of ways. First, it is a good tutorial for the principles that apply in the reactive near-field region. It applies more directly to the proceeding in that a number of commenters continue to insist that BPL emissions from overhead power lines or buildings act as if they were point sources. In that context, it is important to understand just how emissions from a point source behave.

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[3] ANSI-IEEE C63.4 and CISPR 16-2, two widely used commercial emissions Standards, both require vertical scanning of receiving antennas to detect the maximum emissions from all types of equipment under test over all types of ground. (The C63® committee is an American standards organization, so it focuses primarily on the regulations and needs of the FCC, which is a member.)

[4] This is *strongly* supported by measurements made by the Canadian Research Centre, discussed later in this document.

From a point source, E or H fields decay at a rate of 60 dB/decade and 40 dB/decade, respectively, **in the region bounded by $\lambda/2\pi$**, *and at 20 dB/decade beyond that distance*.

It must be emphasized that a distance of 10 meters from this small source, measurements made at all frequencies above 4.77 MHz will be at greater distances than $\lambda/2\pi$. If the premise offered by Current and others that BPL emissions are all point sources were presumed to be correct, then above 4.77 MHz, the entire discussion becomes moot and the FCC can easily set an extrapolation of 20 dB/decade above that frequency because everyone is in some degree of agreement (albeit for different reasons).

There is strong support in industry standards[5] for doing just that, because as outlined in a number of industry standards, emissions outside the $\lambda/2\pi$ boundary should be presumed to decay at a 20 dB/decade rate and, in fact, emissions from a point source decay at exactly that rate if not influenced by a ground plane. (This decay rate also applies well beyond $\lambda/2\pi$ for emissions upward from sources over ground planes, if the point of maximum emissions is found as the starting point and the angle of the decay matches the actual near-field pattern, not simply presumed to be perpendicular.)

Radiating near-field region

Beyond the distance from an emitter bounded by $\lambda/2\pi$, EM fields are radiated. For physically small sources, beyond this region the E and H fields are physically radiating and moving away from the source. For these small sources, beyond that distance, they are approaching being planar and at right angles from each other, with a relationship such that E/H = 377 ohms. This is a classic far-field condition, so for small radiators, there are generally only two regions – the reactive near-field region and the far field region.

For large radiators, however, beyond a distance of $\lambda/2\pi$, fields are also radiated, but points in that region are not approximately equidistant from all portions of the antenna, as they would be at large distances from the source. The field strength at any given point is influenced by radiation from all parts of the radiator, to differing degrees. This region is sharply bounded by $\lambda/2\pi$ in proximity to the large emitter and approximately bounded by a region determined by the dimensions of the radiator as $2D^2/\lambda$ at distances away from the radiator, where D is the largest physical dimension of the radiating structure. The area between the $\lambda/2\pi$ and $2D^2/\lambda$ boundaries is generally known by the term *radiating near field region.* In this region, fields are radiated and moving away from the source, but the interaction between fields radiated by all the different parts of the radiator cause a standing wave vs distance (in all three axes) to develop (with peaks spaced at intervals of approximately 0.5λ).

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[5] From the paper, *Industry Standards Addressing Distance Extrapolation*, Hare, E., provided by ARRL in its Comments in the Further Notice of Proposed Rulemaking (http://fjallfoss.fcc.gov/ecfs/document/view?id=7020039208)

In the radiating near-field region, it is not uncommon for field strength to vary wildly over relatively short distances, especially for large, complex radiators[6].

However, as can be seen in Figures 2 through 4 below, in the radiating near field region, the *peaks* (or average) of those standing waves decrease at 20 dB/decade going away from the source.[7]

Figure 1 (above) illustrates the various near- and far-field regions surrounding a radiating element. For physically small radiators, the radiating near-field region typically does not exist. The fields and the way they behave transition from the reactive-near-field region to far-field conditions at the $\lambda/2\pi$ boundary.

Far-Field Region

For large radiators, beyond a distance bounded approximately by $2D^2/\lambda$ (where D is the largest physical dimension of the radiating structure), far-field conditions are presumed to exist[8]. In the far-field region, EM waves are planar, at right angles, with an E/H ratio of 377 ohms. This boundary is not sharply defined. At distances greater than $\lambda/2\pi$, the standing wave pattern seen vs distance from the radiating source diminishes with distance. At $2D^2/\lambda$, this standing wave is diminished, but still evident, and far-field conditions are not precisely met, but in general, the conditions are met well enough for most practical purposes. It is generally accepted that at distances greater than $2D^2/\lambda$, it is reasonably accurate to presume far-field conditions.

[6] In fact, as shown in Figure 16 and in the standing wave seen in a number of other figures, field strength can actually increase with distance for E or H. Because the fields are not planar and not related by E/H = 377 ohms, in areas where H is high, E is low, and vice versa.

[7] The nulls seen in this pattern theoretically extend to infinity, but in practice, because most line emitters are not infinite nor are they perfect lines, the depth of the nulls, if measured, would typically vary essentially as shown. Because a typical loop antenna used to make measurements below 30 MHz has physical dimension, it is not likely that this loop will capture the depth of a very deep null. The loop accurately measures the peaks of the signals, but in deep nulls, the loop has a capture area that extends past the depth of the null.

[8] For very large radiators, some references indicate that the far-field boundary should be assumed to be at a distance of $0.5D^2/\lambda$. This is technically supportable, but although it reduces the size of the radiating near-field assumptions, it doesn't change the fact that for a large overhead power line radiating for at least 1 km along its length (according to FCC and ARRL measurements), the radiating near-field region is large <u>and gets larger with frequency</u>. At a frequency of 100 MHz, a 1 km long power line has a radiating near field region of 67 km at 10 MHz and 667 km at 100 MHz using the $2D^2/\lambda$ formula and a "mere" 17 km far field boundary at 10 MHz and a 167 km boundary at 100 MHz using the $0.5D^2/\lambda$ formula. The reality is that the near-field region where 40 dB/decade applies is bounded by $\lambda/2\pi$, resulting in a more rational conclusion that the near field region as far as extrapolation applies has a geometry that decreases with increasing frequency. This decrease in near-field region vs frequency is seen in a number of standards, such as ANSI C63.12, where the field-strength is presumed to decay at 40 dB/decade within $\lambda/2\pi$ and 20 dB/decade beyond that distance.

ET-04-37 Comments and Reply Comments: Mixing and Matching

It is clear from some of the Comments and Reply Comments provided in the FNPRM proceeding that some entities do not understand the EM principles involved in the reactive and radiating near-field regions. In these comments, these entities discuss "far field " and "near field" with inaccurate abandon, apparently presuming that there is only one "near field" to consider and incorrectly assuming that the conditions that apply in the reactive near-field region, i.e. decay at 40 dB/decade, applies to the entire "near field" region bounded by $2D^2/\lambda$. The reality behind these misassumptions and misrepresentations is that for neither point sources nor large emitters does field strength vary at a 40 dB/decade rate in the radiating near-field region. (From Current's statements, it appears that it very mistakenly believes that field strength decays at 40 dB/decade at all distances from what it is mischaracterizing as "point sources.")

This misapplication extends into the present FCC rules, as well, where it is presumed that the distances typically used for measurement and reference distances are in the "near field" region below 30 MHz, so thus vary at a 40 dB/decade rate, and in the far field region above 30 MHz. The fallacy of this is readily apparent from the formulas for the reactive near-field boundary and the distance generally assumed to represent far-field conditions. Applying the $\lambda/2\pi$ formula, it is shown that at a distance of 10 meters, points are outside the reactive near-field boundary for all frequencies above 4.77 MHz. Applying the $2D^2/\lambda$ formula, it is shown that as frequency increases, the size of the radiating near field increases, so above 30 MHz, the size of the near field region is larger than it is below 30 MHz. As evidenced by the language of Sec. 15.31 itself[9], these rules should be clarified to better address the way that field strength decays rapidly in the reactive near-field region and at a 20 log rate beyond that distance. (Failure to do so leaves the rules inexplicably presuming far-field conditions in the large radiating near-field region for devices radiating above 30 MHz, but presuming near-field conditions for the radiators below 30 MHz with a smaller radiating near-field region.)

The premise that fields below 30 MHz are in a region that decays at a 40 dB/decade rate is not supported by the EM principles related to the reactive near field region and the principle that above 30 MHz points are in the far-field region is not supported by the principles and formula related to defining the radiating near-field boundary. This makes the 40 dB/decade below 30 MHz rule wrong from two directions, for two different reasons.

This 40 dB/decade premise is supported by those EM principles for frequencies below 30 MHz, *for extrapolations made entirely within the $\lambda/2\pi$ boundary*[10].

[9] The language of Sec. 15.31(f)(2) reads, " . . . <u>Pending the development of an appropriate measurement procedure for measurements performed below 30 MHz</u>, when performing measurements at a closer distance than specified, the results shall be extrapolated to the specified distance by either making measurements at a minimum of two distances on at least one radial to determine the proper extrapolation factor or by using the square of an inverse linear distance extrapolation factor (40 dB/decade)."

[10] At 10 meters, this equates to a frequency of 4.77 MHz.

It is this mixing and matching – an explainable (but incorrect) misunderstanding in light of the incorrect nature of the present FCC rules – that has led to most of the confusion in some of the Comments and Reply Comments. This is best addressed by having rules that do not inadvertently misrepresent known EM theory and the way that fields behave near physically large and small radiators.

Use of free-space models

Some commenters have indicated that free-space models have no applicability to the measurement of BPL systems operating over a ground plane. In fact, in general, those commenters that are associated with the BPL industry have indicated that all models and measurements that do not support their premise that fields from point sources connected to long lines located at various heights above ground decay at a 40 dB/decade rate for distances of 10 to 30 meters somehow don't apply to BPL. The reality is that the EM principles that apply to everything else apply to emissions from BPL systems as well[11].

These free-space models have direct applicability and bearing on the issues being discussed in this rulemaking. Clearly, the principles of the way that field strength decays with distance are best illustrated with simple models. All of the principles found in the ways that simple models behave are seen in more complex models. The difference is that in complex models, those principles sometimes interact to produce a more complex result. That result, however, will not be dramatically different in kind than what is seen in the principles explained in simple illustrative models. If BPL had emissions with characteristics somewhere between a point source and a line source, the principles of both point and line sources would be seen in the combination.

More specific to the rulemaking, several commenters have continued to insist that BPL is a point source. This is not true, but if this premise were correct, the model for a point source (or small electric or magnetic dipole) would apply, and in that scenario, the best model to use is that of a small radiator. (Of course, to those claiming that BPL is a point source, it is described in comments as a point source that has fields that don't decay the same way that the models of a point source decay. The premise of the BPL industry is that BPL is a point source whose fields decay at 40 dB/decade at all distances from the source, while the point source models and generally accepted EM theory are clear that fields from a small radiator decay at 20 dB/decade beyond $\lambda/2\pi$.).

In this paper and in other Comments and Reply Comments in this proceeding, ARRL has sometimes used models of small and line emitters in free space. The use of free-space models is also directly applicable to the considerations of this proceeding. Although the test methodology under discussion is all related to tests done at 1 meter height, the real purpose of any emissions limits or measurements of systems to ensure compliance with

[11] There are considerations to the emissions from overhead lines that are somewhat unique to BPL. These are discussed later in this paper. It must be noted now, however, that these considerations point directly away from the use of 40 dB/decade to extrapolate for measurements made at short horizontal distances from overhead lines and toward the use of an extrapolation factor even lower than 20 dB/decade for some measurements.

those limits is to offer some degree of protection to licensed services[12]. Figures 5 through 7 below show the calculated emissions from line emitters. Figure 8 also contains a model of a line emitter modeled over ground with typical conductivity and dielectric constant[13]. Although this figure shows that the physics of the interaction of that line emitter with the ground plane cause field-strength to decay with distance along the ground with respect to the slant-range to the overhead radiator, the figure, when compared to Figures 5 and 6, shows that at the upward angle where field strength is maximum, 60 degrees, the decay of field strength with distance precisely matches the free-space model. Models of line emitters are the most fundamental representation of the way that field strength varies in general.

In summary, the use of free-space models is reasonable to act as a good tutorial for the differences between point sources, line emitters and other large radiators and as a precise indicator of the way that field strength varies with distance at upward angles from overhead power lines[14].

However, as will be shown later, free-space models are not necessarily a good indicator of how field strength varies along the ground, especially at distances closer than 10 meters horizontally from an overhead radiator.

Line emitters

As clearly seen in tests done by the FCC, BPL emissions from overhead power lines are not a point source. Note the comment in Figure 3: "*** NOT A POINT SOURCE ***"

[12] Limits on emissions do not offer complete protection from harmful interference to licensed services. Limits generally limit the geographical area within which interference is possible or likely. This will reduce the number of harmful interference problems to a level that may be practical to mange.
[13] The ground modeled has a conductivity of .005 S/m and a dielectric constant of 13.
[14] BPL industry comments have misrepresented ARRL's information on this point. At this point, ARRL is in no way suggesting that measurements above the line are practical, safe or necessary, although they are technically and logistically feasible. ARRL is noting that the way that radiated emissions occur and vary at upward angles from overhead lines must be understood and considered because it at these upward angles that antennas will generally be located.

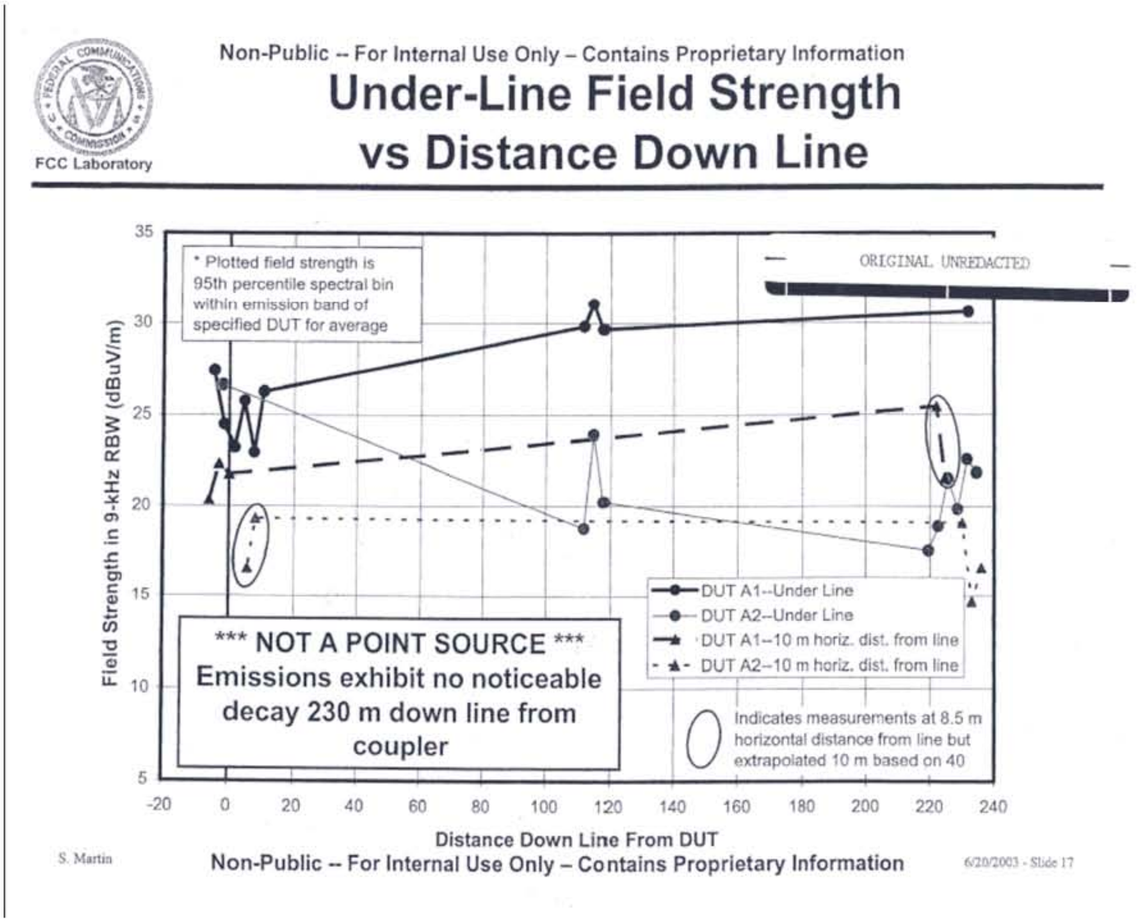

Figure 3 – Original un-redacted slide from FCC staff report on Access BPL. The FCC measurements were very clear: BPL connected to overhead lines is not a point source.

Figure 4 below shows FCC measurements made by the FCC at the BPL site in Briarcliff Manor, NY. Although it shows a peak near the point where the BPL signal is coupled on to the line, it is readily apparent from this graph and video documentation provided in this proceeding by the FCC engineering staff, BPL is not a point source. The emissions from this overhead power *line* is, not surprisingly, very characteristic of a line emitter.

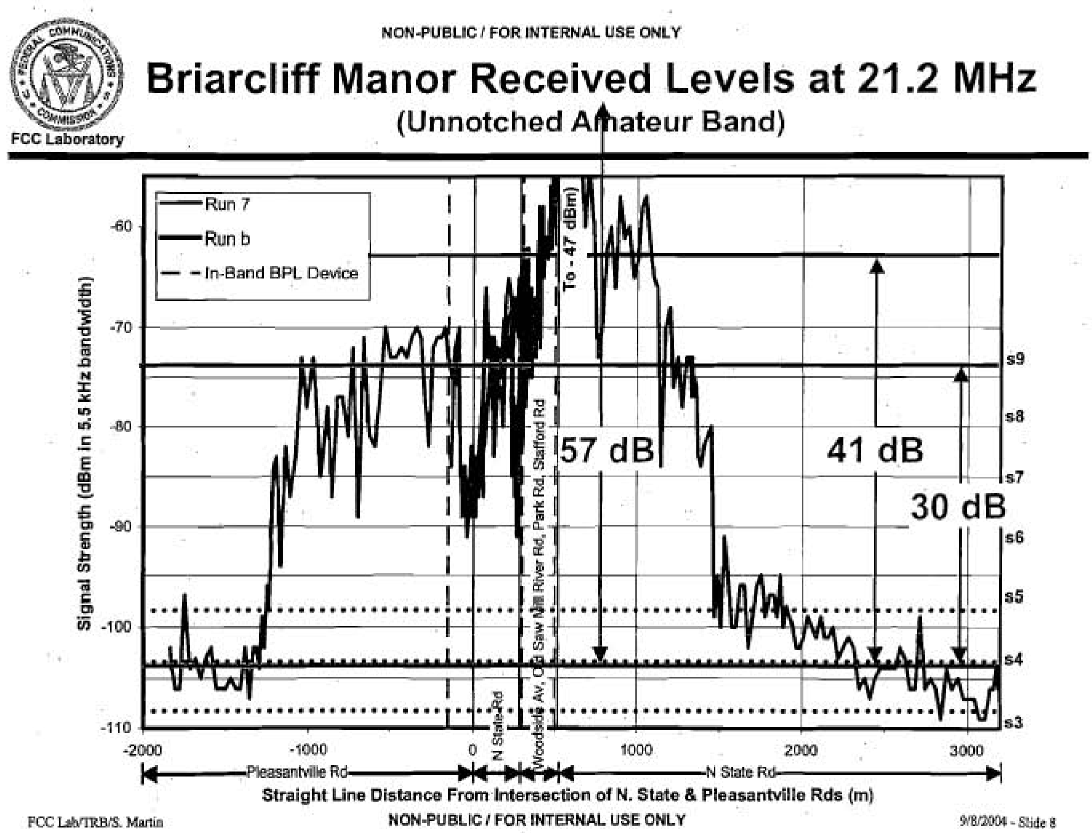

Figure 4 – This is a measurement made by FCC technical staff of the emissions from an overhead power line carrying BPL in Briarcliff Manor, NY. Characterizing this emission as a point source is very evidently incorrect. Overhead power lines act in exactly the same way any other long line source acts. For the most part, this source is a line emitter and is best described by a line model.

A line emitter behaves differently than a point source. Although the reactive near-field region does still exist, because each point in that region is also in the radiating near-field region of parts of the line that are farther away, the end result is that from a line emitter, field strength decays at a 1/D rate (20 dB/decade). With the standing wave of field strength that develops along the line and away from it, the peaks of the E and H field are not at the same physical points in space, at the maxima for each the fields from a line emitter generally decay at a 20 dB/decade rate within the reactive near-field region. In the radiating near field region, a standing wave is developed, but the peaks of this standing wave in this region also decay at a 20 dB/decade rate.

This is best illustrated with Figures 5, 6, 7 and 8 below.

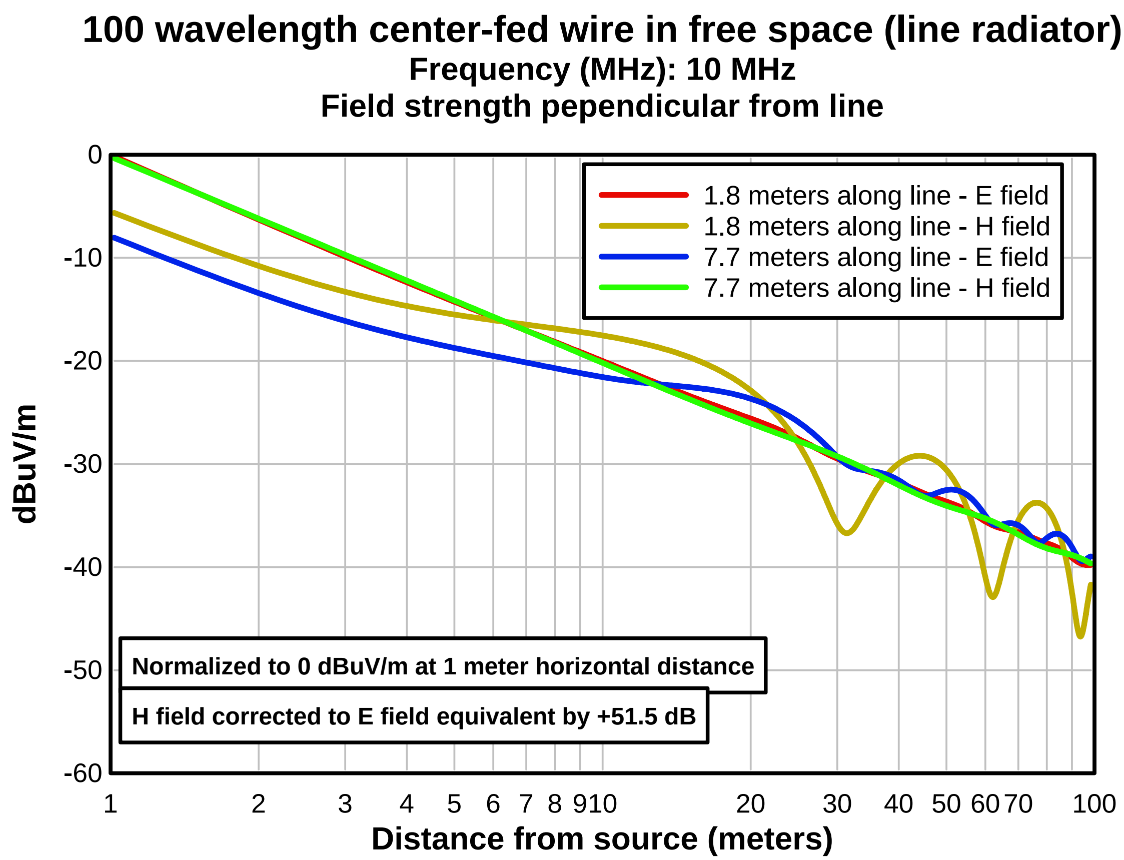

Figure 5 – This model shows the way that field strength decays from a line emitter in free space. The model is of a 100 wavelength line, with a power source in the center. This was modeled at a frequency of 10 MHz. (This model also generally applies upward from a line emitter over a ground plane.) In this case, the points of maximum emission along the line at a distance of 1 meter were first determined, at a distance of 1.8 meters from the center of the line for the E field. The point of maximum H field along the line was at a distance of 7.7 meters. At the maxima, the E and H fields decay at a 20 dB/decade rate. It can also be seen, incidentally to this discussion, that if the maxima are compared, E/H is very close to 377 ohms. This is strong support for the use of a magnetic loop to measure compliance, if the points of maximum emission are found and measured.

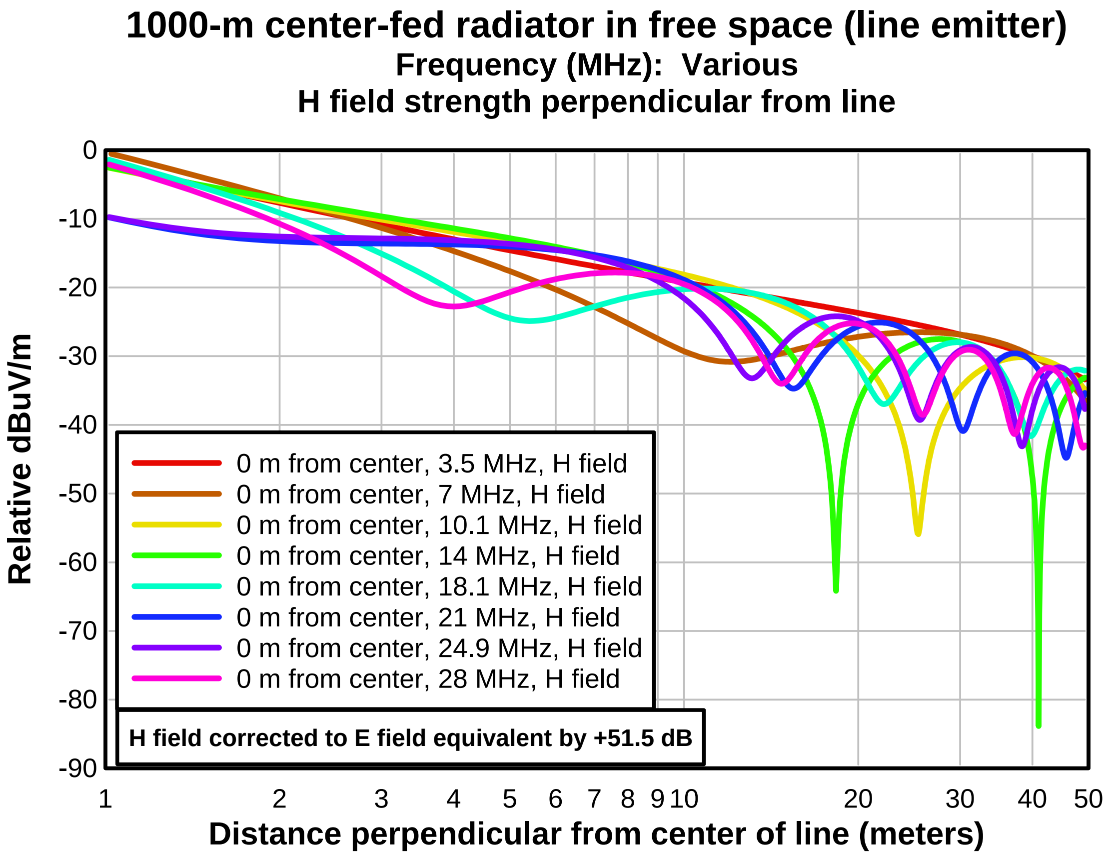

Figure 6 – This shows the model of field strength from line emitters for different frequencies. The depth of the standing waves in this graph is determined mostly by the resolution of the distance steps used to make this calculation. This also shows a 20 dB/decade decay rate, for the peaks of the standing wave, for all frequencies calculated. It also shows that for this line emitter, the points of maximum E and H are at an E/H = 377 ohms relationship.

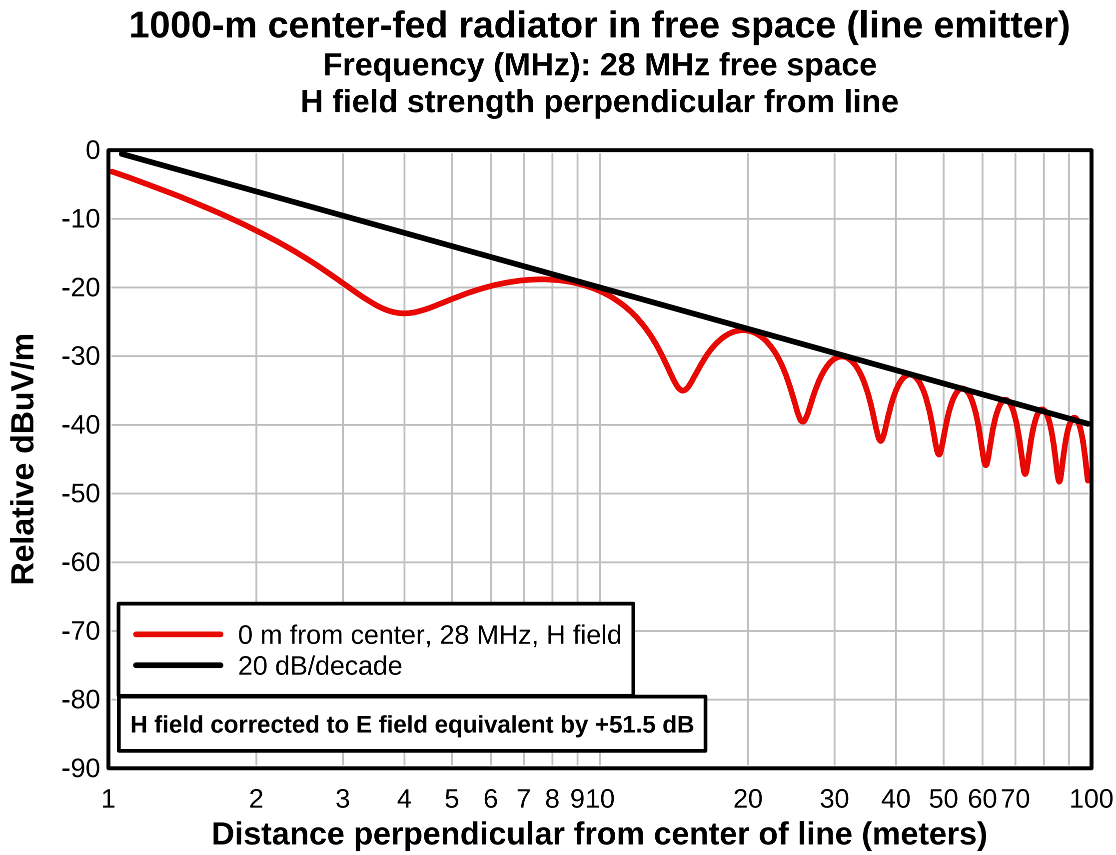

Figure 7 - This shows the same data as seen in Figure 4, but only for the 28 MHz calculation H field. This less-cluttered graph makes it easier to see the way that field strength varies with distance from a line emitter.

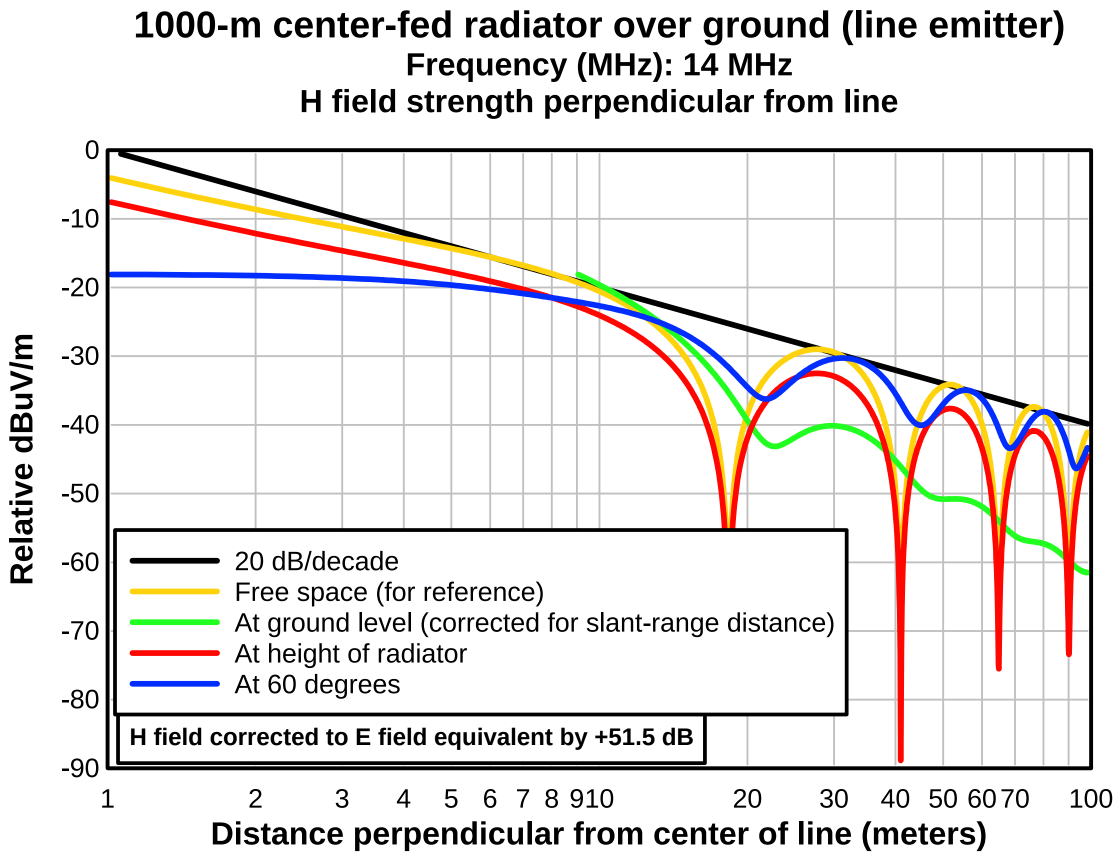

Figure 8 – This is a graph showing the calculated field strength from a line emitter over ground. The frequency of the calculation was 14 MHz. The height of the radiator was 10 meters and the ground had average conductivity and dielectric constant (0.005 S/m and a dielectric constant of 13). The graph shows a free space calculation for reference (yellow), a calculation made horizontally at the height of the radiator (red) and a calculation made starting at a point 10 meters in height and upward from the emitter at a 60 degree angle (blue). (This is the angle at which maximum emissions occur in this radiator at this frequency.) The influence of the ground plane can also be seen in the green line data.

Line Emitters over Ground

Figure 8 above shows the effect that ground can have on the emissions from overhead power lines. As will be shown below, the graph showing calculations at 1 meter height near the ground is specific only to the frequency used to make the calculation.

In many cases antennas of nearby radiocommunications systems are located at heights greater than overhead power lines. Any extrapolation based on measurements made at ground level must correlate well to emissions at upward angles if the limits specified are to offer any protection to those licensed stations.

Several of the papers ARRL filed into the record in the FCC BPL proceeding correlates ground-level measurements to upward angles, as does this paper. This generally involves adding a height correction to the measurements made at ground level. To simplify that, and to provide conservative results, this paper does not generally do so, but instead uses free space models to show the underlying trends involving extrapolation vs distance at various frequencies for large and small emitters.

In its Further Notice of Proposed Rulemaking Reply Comments , Ambient provided a paper[15] by Dr. Yehuda Cern, a consultant to the Ambient Corporation.[16]. This paper purports to show the way that field strength decays with distance over ground of typical conductivity and dielectric constant.

The paper indicated that Cern had run hundreds of simulations. The model that Cern chose to include in the paper as a representation of power lines correctly includes three phases (although many BPL systems are installed on lines with two phases, or even a single phase), but in the model, there are no loads or imbalances typical of BPL systems. The model also contains zero loads, representing transformers that are typically found on power lines every 50 to 500 meters, depending on the population density. There is a neutral wire modeled at 4 meters height, but the wire is not grounded. The feed point is perfectly balanced and the line, un-terminated at both ends, is fed exactly in the center. None of these attributes of the model are typical of BPL systems found in various deployments.

The data presented by Cern are also insufficient in several key ways:

- The data and conclusions are valid only for points along the ground at 1 meter height.
- The paper does not address field strength and decay with distance for any points above 4 meters in height, where many receive antennas will be located.
- The paper does not account for the skew in azimuth angle of decay of field strength with distance from a large radiating line source
- The increments down the line are too coarse to permit full analysis of the actual decay rate of all frequencies, especially considering the skew from perpendicular in the near-field pattern seen to one degree or another in each of the models.

See Figure 9 below. This graph, also provided by ARRL in a paper authored by Hare as an Exhibit in ARRL's Comments in the Further Notice of Proposed Rulemaking (FNPRM), shows an overhead view of the field-strength surrounding an NTIA-modeled power line of the Amperion BPL system that had been installed and operated by PPL in Allentown, PA. The skew in angle of decay, the near-field pattern and wide variability of the decay rate at different points along the line is readily apparent.

[15] Insert reference

[16] Cern is also a former Ambient employee and a licensed radio Amateur and ARRL member.

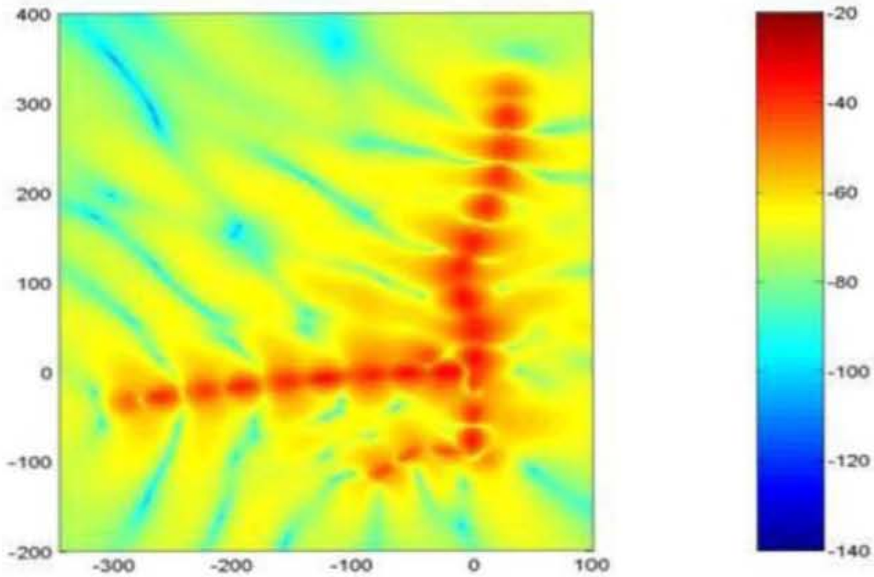

Figure 9 - This shows a bird's eye view of the field strength from an overhead power line, based on a model from the NTIA Phase I report, of the system in Allentown, PA. Note that the field strength decays at different rates from each of the maxima along the line. The decay also typically shows a skew from perpendicular. It is not possible to find a real extrapolation from a measurement of 4 points in this environment. This graph alone, based on NTIA models, is sufficient explanation about why it is simply not possible to make a small number of measurements in an in-situ environment to determine a "site-specific" extrapolation value. When one would obtain a different "site-specific" number for each distance from a radiating source as one measures into and out of the nulls that will exist near any large radiator; when one would obtain a different value for each frequency and a different value on one side of the line than the other, the methodology to make such a site-specific measurement is fundamentally flawed.

All of these factors have resulted in significant errors in Cern's conclusion. The results that the paper shows have been carefully selected from the much larger set of data from the hundreds of simulations run, apparently based on whether those data supported the premise that extrapolation should remain at 40 dB/decade below 30 MHz. Obvious steps such as looking at the near-field pattern that skews the decay from perpendicular were not done, as one example.

ARRL entered the parameters for the overhead line that Cern described in his paper into an antenna model, run using EZNEC Pro/4 V. 5.0, using the NEC-2 calculation engine[17]. The model ARRL used included three phases, spaced 1 meter apart. The height of these wires is set at 12 meters above ground with a conductivity of 0.005 S/m and a dielectric constant of 13. A neutral wire is modeled at 4 meters. All wires are 500 meters long.

[17] For ungrounded wires and unburied wires, NEC-2 gives essentially the same results as NEC-4.

The following graphs show the field strength of this model at three different Amateur frequencies: 3.5 MHz and 14 MHz. These are bird's eye views of the H field strength, expressed in relative db, at 1 meter and 23 meters in height. (A height of 23 meters was chosen to be 11 meters above the height of the 12-meter high line, corresponding to the distance from that line to the 1-meter height used for measurements. This allows easy comparison of the results for field-strength-vs-distance above and below the line[18].) The horizontal distances have been corrected for slant range.

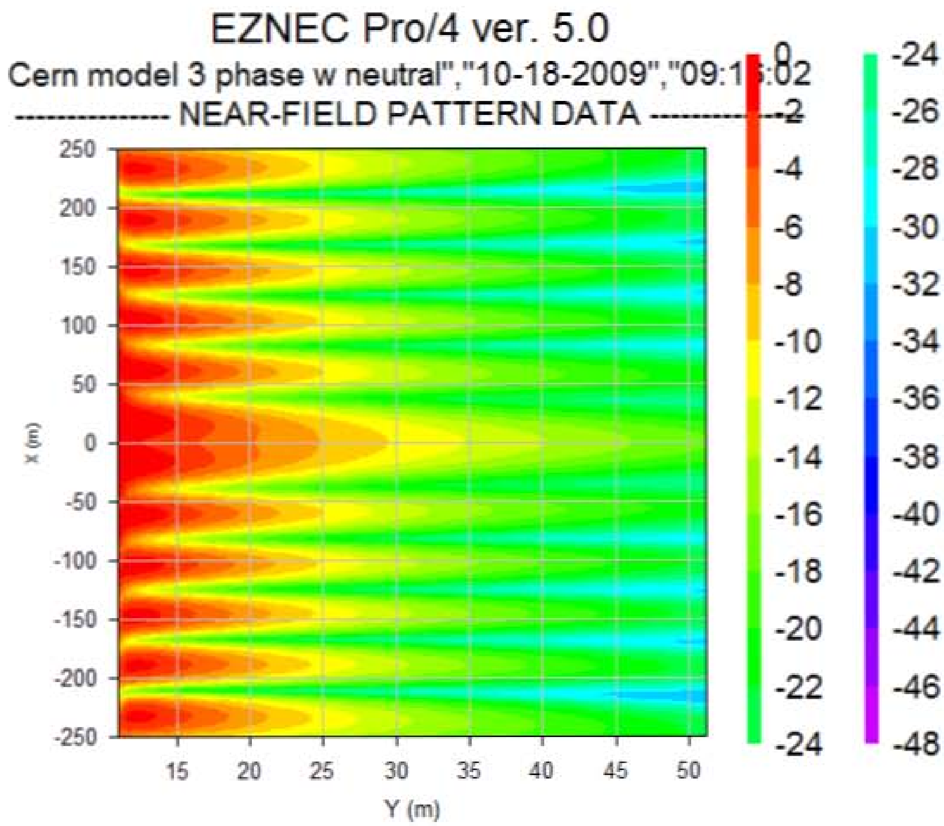

Figure 10: 3.5 MHz, 1 meter height – This is a bird's eye graph of a model with parameters described in the Ambient Corporation Reply Comments. The model consists of 3 phases, separated by 1 meter, at a height of 12 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 3.5 MHz. The data show the H field strength in dB at a height of 1 meter above ground with a conductivity of 0.005 S/m and a dielectric constant of 13.

[18] To forestall the inevitable response to this, ARRL will be clear that it agrees that measurements should not be made above overhead power lines. These data are included in this paper to allow the relationship between field strength at 1 meter height to be compared to the locations above the line where HF and VHF antennas are apt to be located.

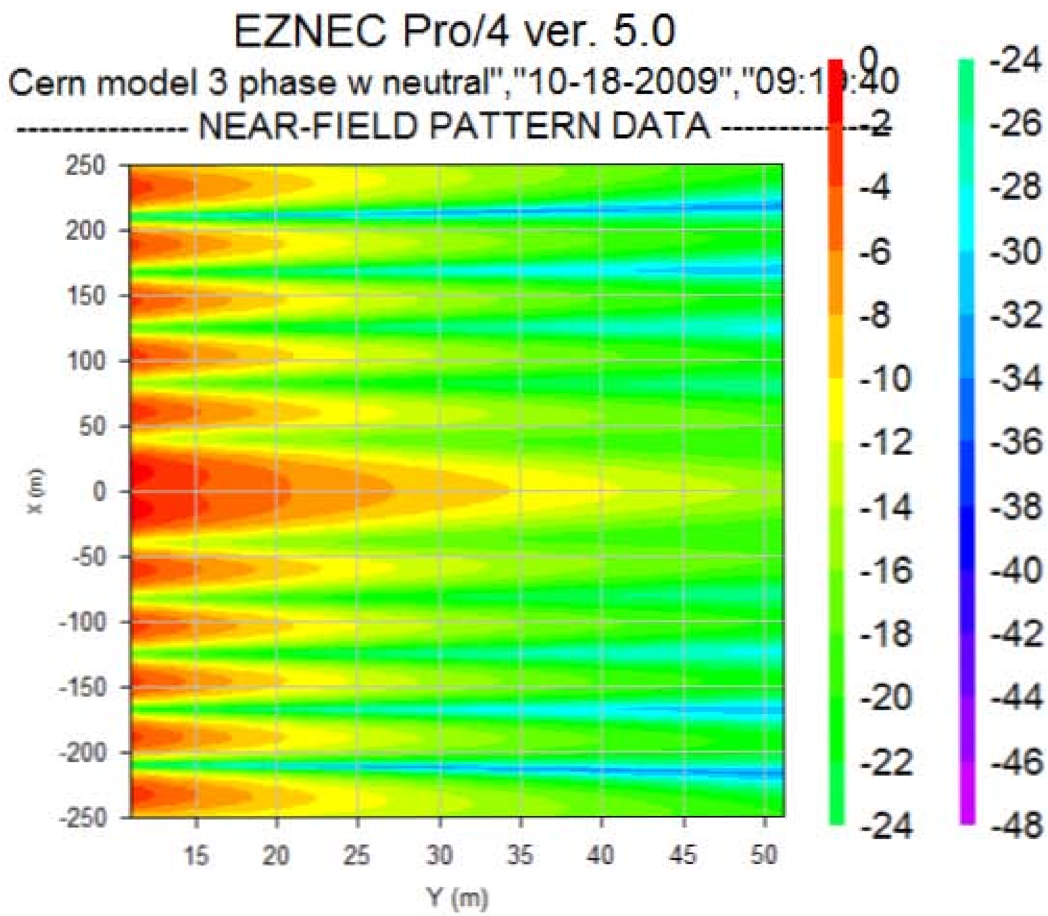

Figure 11: 3.5 MHz, 23 meters height – This is a bird's eye graph of a model with parameters described in the Ambient Corporation Reply Comments. The model consists of 3 phases, separated by 1 meter, at a height of 12 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 3.5 MHz. The data show the H field strength in dB at a height of 23 meters above ground, to give the same slant-range distance to the line as the calculations at 1 meter height. The ground has a conductivity of 0.005 S/m and a dielectric constant of 13.

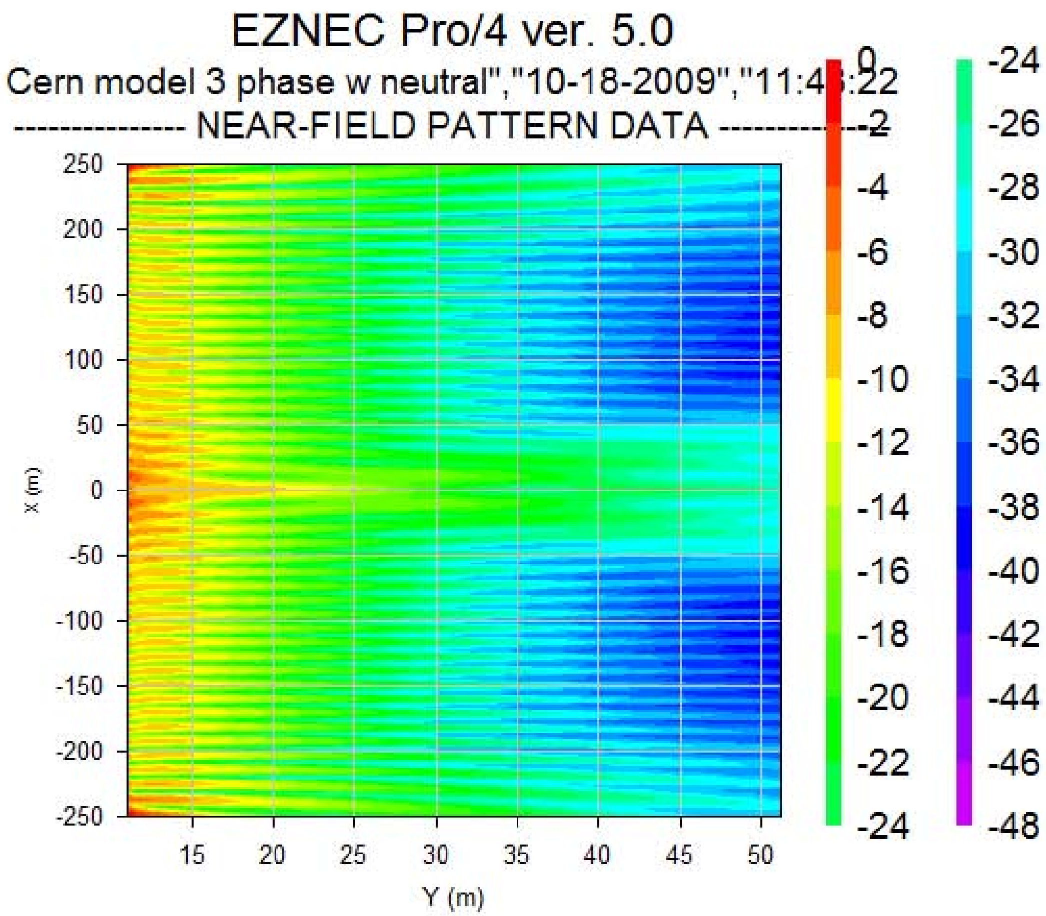

Figure 12: 14 MHz, 1 meter height – This is a bird's eye graph of a model with parameters described in the Ambient Corporation Reply Comments. The model consists of 3 phases, separated by 1 meter, at a height of 12 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 14 MHz. The data show the H field strength in dB at a height of 1 meter above ground. The ground has a conductivity of 0.005 S/m and a dielectric constant of 13.

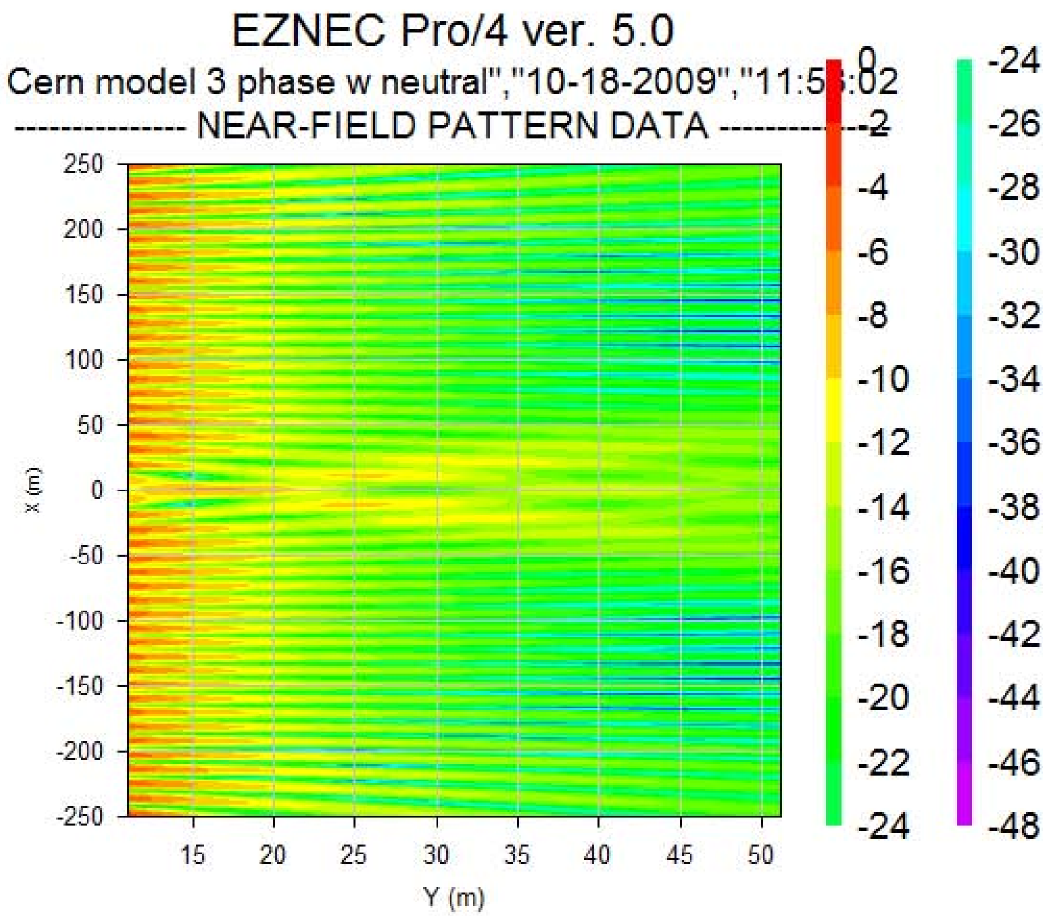

Figure 13: 14 MHz, 23 meters height – This is a bird's eye graph of a model with parameters described in the Ambient Corporation Reply Comments. The model consists of 3 phases, separated by 1 meter, at a height of 12 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 14 MHz. The data show the H field strength in dB at a height of 23 meters above ground, to give the same slant-range distance to the line as the calculations at 1 meter height. The ground has a conductivity of 0.005 S/m and a dielectric constant of 13.

Table A: Extrapolation analysis of the data in Figure 10 and Figure 11 for 3.5 MHz

Start point	End point	Distance along line	Extrapolation
10m horiz/1m height at max -16 m along line	30 m horiz/1m height perpendicular	-16 m	32.1 dB/decade
10m horiz/1m height at max -16 m along line	30 m horiz/1m height at max	0 m	27.6 dB/decade
10 m horiz/1m height at max	30 m horiz/23 m height at max	0m	22.7 dB/decade

Table B: Extrapolation analysis of the data in Figure 12 and Figure 13 for 14 MHz

Start point	End point	Distance along line	Extrapolation
10m horiz/1m height at max 19 m along line	30 m horiz/1m height perpendicular	19 m	42.2 dB/decade
10m horiz/1m height at max 19m along line	30 m horiz/1m height at max	-11 m	32 dB/decade
10 m horiz/1m height at max	30 m horiz/23 m height at max	0m	8.4 dB/decade

As can be seen with a careful look[19] at Figures 10, 11, 12 and 13, and Table A and B, the decay of field strength with distance does not decay at the same rate for different frequencies, at different points along the modeled line or at different heights. A measurement made at 10 m horizontally along the line at 1 meter extrapolates at approximately 40 dB/decade *along the ground, but <u>only if measurements are made perpendicular to the measurement point, despite the fact that the field strength is decaying least rapidly along a line that is **not** perpendicular to the overhead line.</u>* Measuring or calculating at a perpendicular angle is going from a maximum point to a point located (to some degree or another) partially within a null in the pattern. Although the principle of measuring at various points up or down the line at increments if ¼ wavelength at the mid-point of the frequency of the emission is intended to find the maxima

A Better Model

The plotted field strength along the line of the model developed by Cern does not correlate well with the data measured by the FCC engineering staff in the Ambient BPL system in Briarcliff Manor, NY. ARRL developed a model[20] that includes transformers

[19] The color differences between the 2 dB steps can be difficult to discern
[20] This model is provided as Appendix A of this paper.

and a grounded neutral.   The heights of the overhead lines in this model are 10 meters for the phase lines and 4 meters for the grounded neutral.

As can be seen in Figures 14 and 15, this model much better simulates the conditions measured by the FCC as seen in Figure 4.

The validity of simple models, however, is supported by the general results from calculations made on this ARRL model.   The data for field strength at 1 m and 19 meters height are show in Figures 14 and 15 below. Although these models show a more reasonable and representative of the decay of field strength along the line, they also show similar decay of field strength vs horizontal distance from the line as seen in the Cern models, starting with the point of maximum emissions along the line and extrapolating to a point 30 meters distant perpendicularly, a point 30 meters distance at the maximum for that distance and a point 30 meters distant at points upward from the line.

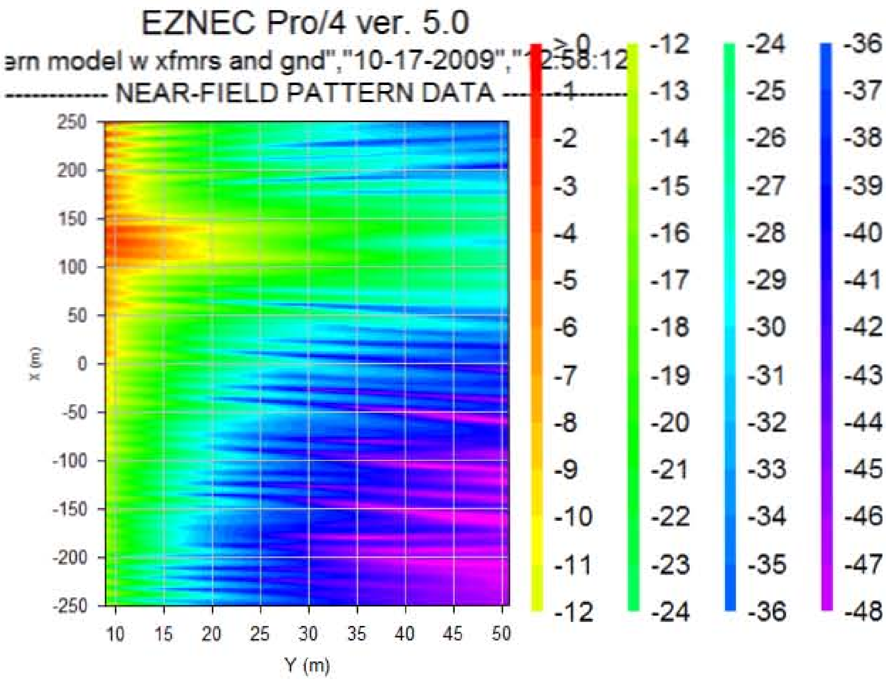

Figure 14:   14 MHz, 1 meter height: – This is a bird's eye graph of a model developed by ARRL, adding loads to represent step-down transformers to the phases and grounds to the neutral wire to the model developed by Cern. The model consists of 3 phases, separated by 1 meter, at a height of 10 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 14 MHz. The data show the H field strength in dB at a height of 19 meters above ground, to give the same slant-range distance to the line as the calculations at 1 meter height. The ground has a conductivity of 0.005 S/m and a dielectric constant of 13.

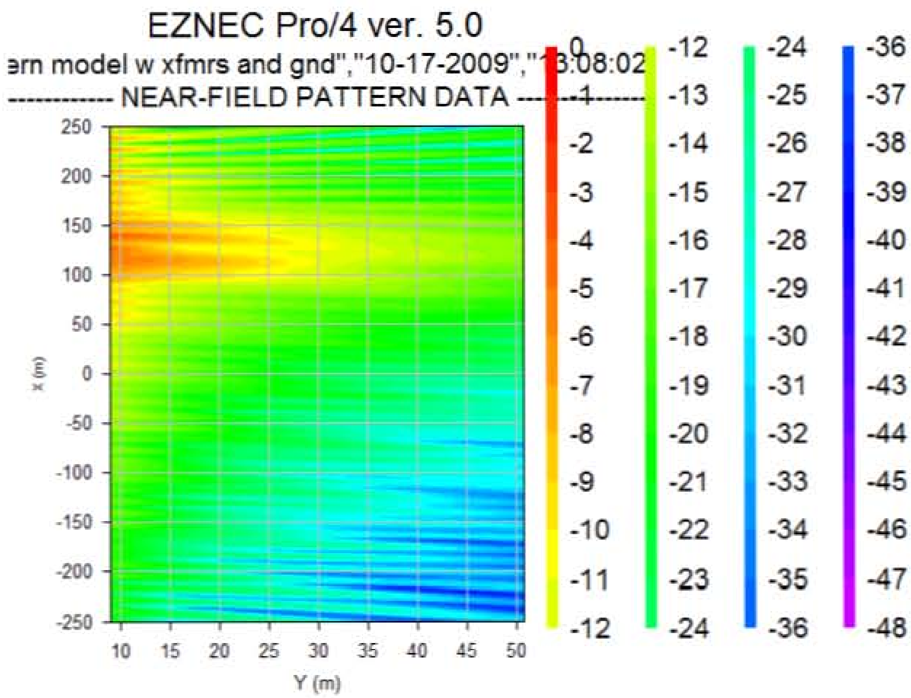

Figure 15: 14 MHz, 19 meters height.: This is a bird's eye graph of a model developed by ARRL, adding loads to represent step-down transformers to the phases and grounds to the neutral wire to the model developed by Cern. The model consists of 3 phases, separated by 1 meter, at a height of 10 meters and an ungrounded neutral wire at a height of 4 meters. All wires are 500 meters long. The horizontal axis (labeled Y) shows the slant-range distance of the calculation point from the overhead line carrying the simulated BPL signal. The vertical axis is distance along the line. The frequency for this calculation is 14 MHz. The data show the H field strength in dB at a height of 19 meters above ground, to give the same slant-range distance to the line as the calculations at 1 meter height. The ground has a conductivity of 0.005 S/m and a dielectric constant of 13.

Table C: Extrapolation analysis of the data in Figure 14 and Figure 15 for 14 MHz

Start point	End point	Distance along line	Extrapolation
10m horiz/1m height at max 125 m along line	30 m horiz/1m height perpendicular	125 m	43.8 dB/decade
10m horiz/1m height at max	30 m horiz/1m height at max	109 m	32.0 dB/decade
10 m horiz/1m height at max	30 m horiz/23 m height at max		(16.1 dB/decade)

The points emphasized by this model are that the effects described in this paper are seen across a range of possible radiating line structures and those simple models do provide a reasonable way to evaluate trends in the way that field strength decays with frequency.

$\lambda/2\pi$ vs line source vs point source

Some of those that provided Reply Comments questioned what they believed to be an inconstancy between ARRL's position that BPL is not a point source and ARRL's two positions with respect to extrapolation (one being that a 20 dB/decade factor is reasonable but the other indicating that within the $\lambda/2\pi$ region, fields decay more rapidly.) The purported inconsistencies are really directed toward the nature of the compromise that is part of those two positions.

Although it is clear that BPL is not a point source, in looking at the models, it is also evident that there is a peak (ranging from modest to significant) near the point where signals are injected onto overhead lines. In this case, although the line models don't show it clearly, it is possible that in some cases, BPL line emitters may exhibit a faster decay rate than 20 dB/decade within the $\lambda/2\pi$ region. Smaller emitters, such as pad-mounted transformers, are expected to show this increase in decay rate within $\lambda/2\pi$. For those reasons, and the fact that industry standards that deal in any way with distance extrapolation below 30 MHz typically permissively stipulate a 40 dB/decade extrapolation within the $\lambda/2\pi$ region, it would also be a reasonable choice to extrapolate at 40 dB/decade within $\lambda/2\pi$ and 20 dB/decade beyond that region in the radiating near field and far-field regions.

Horizontal distances closer than 10 meters

In all of the antenna models ARRL has run for multi-conductor overhead power lines, in the area closer than 10 meters horizontally from the line, field strength can behave in unexpected ways. The following two graphs below illustrate that point. In Figure 16, the field strength below the line is seen to be increasing with increasing horizontal distance. This is a graph of the model in Appendix A, on 14 MHz.

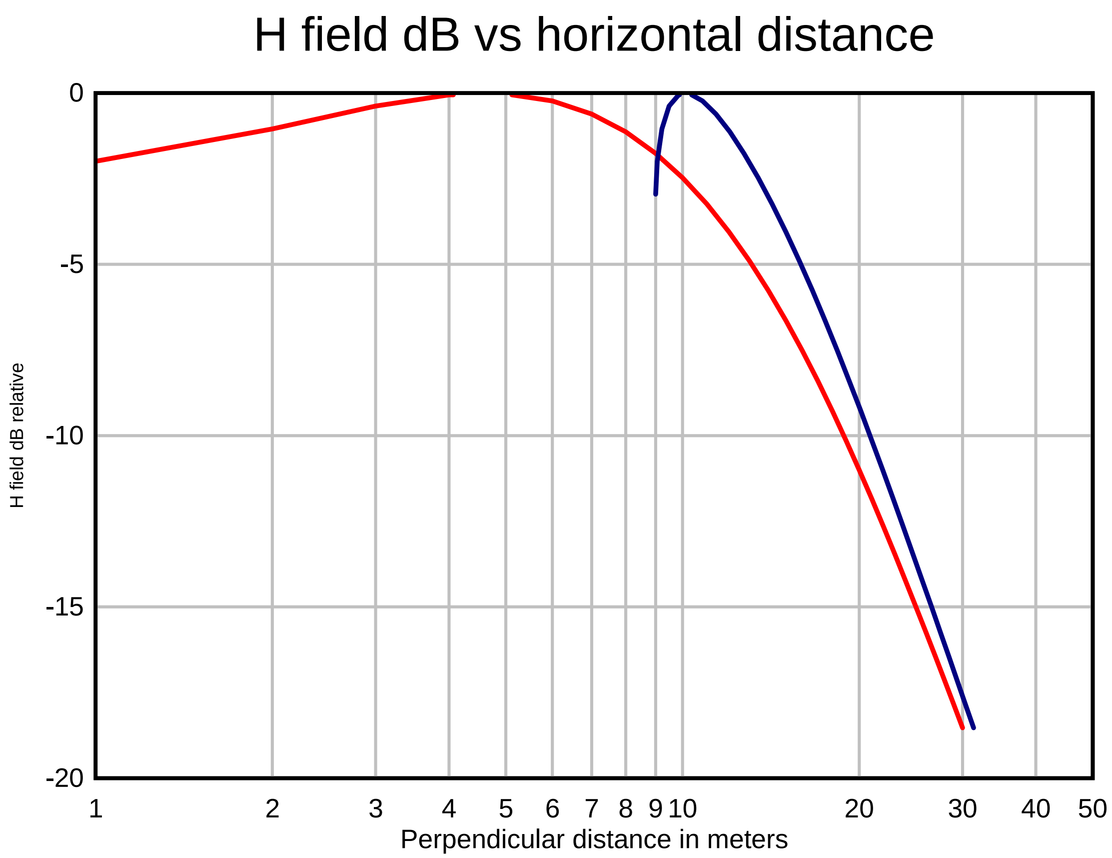

Figure 16 – This shows that at horizontal distances close to an overhead power line, field strength decreases with decreasing horizontal distance. This is a model of an overhead power line, at the point of maximum emissions away from the line perpendicularly. (This is not the azimuth angle of actual decay with distance, but it does represent the way that field strength is being measured now under FCC rules.) The modeled power line is comprised of three phases, with loads to simulate step down transformers, at a height of 10 meters. There is a grounded neutral wire at 4 meters in height. The red line shows the field strength data plotted against horizontal distance. The blue line shows the same data plotted against slant-range distance. At slant-range distances of 10 meters or less, measurements of field strength at that short distance will significantly underestimate the field strength at greater distances, no matter what extrapolation factor is used.

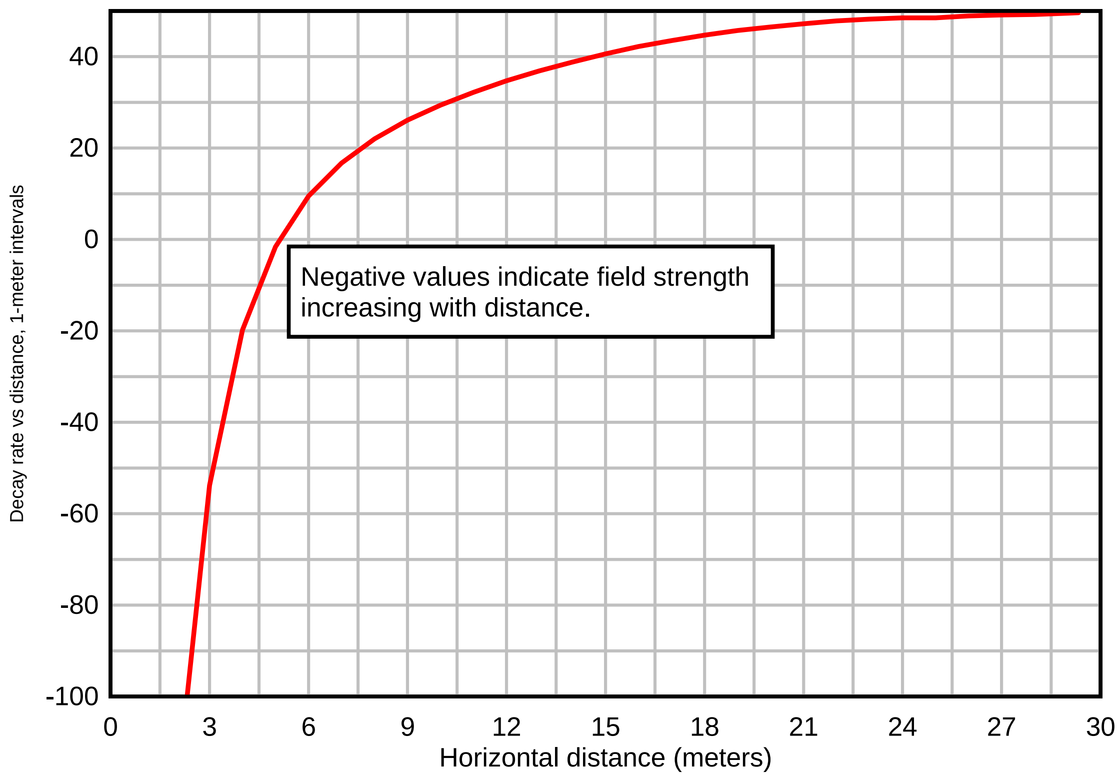

Figure 17 – This shows the same data, but with an extrapolation factor calculation done in 1- meter instruments. The actual field-strength decay with distance varies strongly with the distance from the radiating source. In this case, field strength is increasing with increasing distance for points closer than 6 meters horizontally from the line. No matter what extrapolation factor is used, at close distances to the line, extrapolation will be in error. This graph shows the fallacy in using slant-range distances to overhead power lines as part of the function to determine extrapolation. A purported "site-specific" extrapolation cannot be said to exist for a line whose extrapolation varies along its entire length.

EMC Standards and Precedents for Finding the Point of Maximum Emissions

Maximum Emissions

<u>Any emitter above any ground surface will emit its field-strength maxima upwards</u>. The intent of EMC emission Standards is to find the maximum emissions from the EUT. This maximum-emissions assessment is done by measuring the radio reflections upward from a ground plane, however imperfect (even dirt or asphalt). In the US, this is documented in ANSI-IEEE C63.4-2003, which requires the receiving antenna be scanned vertically

from 1-4 meters in height to record the maximum emissions from the EUT.[21] It also requires the EUT to be rotated and tested using both antenna polarities. If the EUT cannot be rotated, its maximum emissions must be measured by vertically scanning the sensing antenna at a minimum of 16 azimuth angles around the EUT. Cables and wires must be manipulated during exploratory measurements to assure they are producing the maximum emissions during the testing.

The European equivalent document, CISPR 16.2 (1996), also requires 1-4 meter vertical antenna scanning for 10m emission limits, as well as 2-6m vertical antenna scanning for 30m emission limits, measured in both polarities[22], such as the 30m limits adopted by the FCC here in the US for BPL systems operating below 30MHz. These maximum emissions are measured first; before comparing them to the radiated emissions limits for that type of device, which is set by various national regulation. (Radio services and other "victim" equipment are only protected by the emissions limits implemented through National regulations and by the avoidance of "harmful interference," usually enforced through complaints) Figure 14 from this Standard, shown below as Figure 18 below, illustrates the concept of maximum readings being attained at the receiving antenna by scanning its height above the ground. This field-strength maximum is created by the reinforcement of direct and ground reflected waves arriving at the receiving antenna.

[21] ANSI C63.4-2003: Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

[22] CISPR 16.2 (1996) Specification for radio disturbance and immunity measuring apparatus and methods - Part 2: Methods of Measurement of disturbances and immunity

CISPR 16-2 © IEC:1996 – 111 –

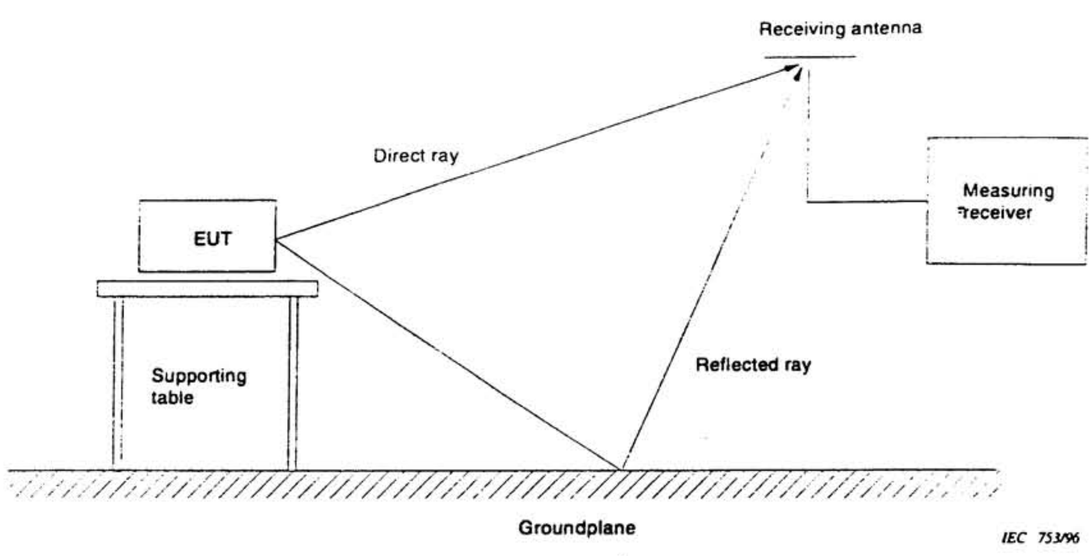

Figure 14 – Concept of electric field strength measurements made on an open area test site with the direct and reflective rays arriving at the receiving antenna (see 2.6.2.2)

Figure 18 – Field strength maxima caused by direct and reflective rays at the antenna

As in North America, CISPR 16.2 requires manipulation of the I/O lines of the product being tested and EUT azimuth rotation to assure it is producing maximum emissions. If using an outdoor site without a ground plane, measurements are still valid for that location. If a stationary product cannot be rotated, an obstruction-free area is recommended as shown in Figure 15 (shown below as Figure 19) from CISPR 16.1 (1993).[23]

[23] CISPR 16.1 (1993) Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus

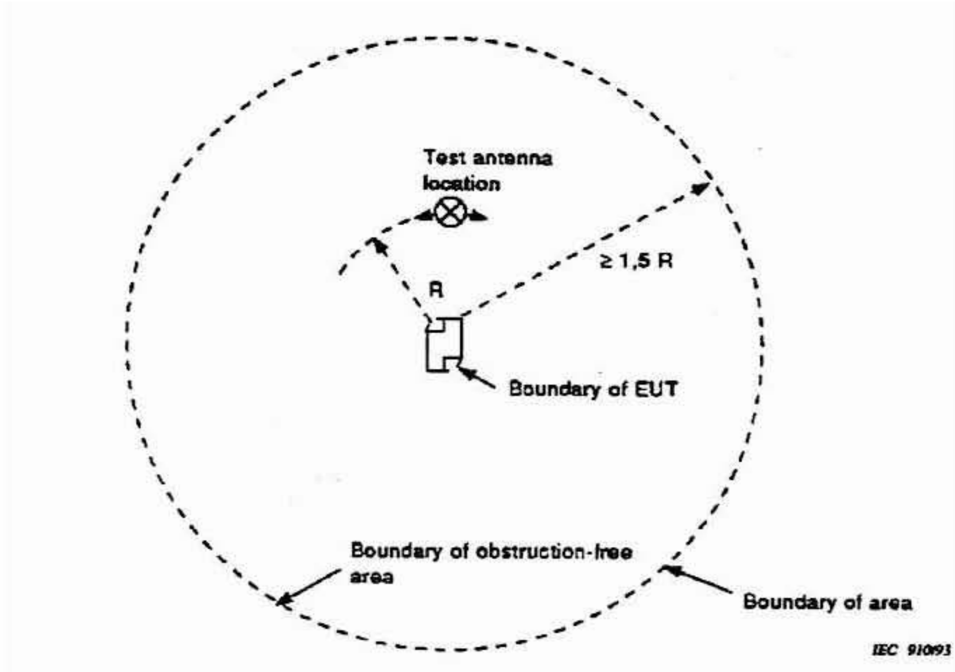

Figure 15 – Obstruction-free area with stationary EUT. (Subclause 16.3)

Figure 19 – Obstruction-free area around stationary EUT

These three essential concepts of maximizing detected emissions by scanning the sensing antenna vertically, rotating the EUT or rotating the sensing antenna about it, and manipulating the I/O arrangement for maximum emissions before comparing the measurements against relevant emission limits are referenced in many other EMC Standards. The European Standards for industrial environments and protective relays in substations require that the maximum emissions be measured. [24, 25] The American standard for radio noise measurements from overhead lines and substations requires the measurement of maximum emissions, [26] as does the Canadian standard for noise from AC power systems.[27] Measuring maximum emissions before comparing the results to limits on those emissions is also required in the European radio noise emission standards for

[24] IEC 61000-6-4 - 1997: Part 6: Generic standards – Section 4: Emission standard for industrial environments

[25] IEC 60255-25 - 2000-03: Part 25: Electromagnetic emission tests for measuring relays and protection equipment

[26] ANSI/IEEE Std 430-1986 IEEE Standard Procedures for the measurement of Radio Noise from Overhead Power Lines and Substations

[27] CSA National Standard of Canada CAN3-C108.3.1-M84 Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems, 0.15-30 MHz

Information Technology Equipment[28], Industrial, Scientific and Medical RF equipment,[29] motor-operated and household appliances[30] and electrical lighting equipment.[31]

Protection of other equipment

Radio services and other "victim" equipment are primarily protected by the emission limits implemented through National regulations. Alternately, in North America, victims are also protected by the concept of "harmful interference," enforced through a complaint process.

In the United States, the FDA Reviewer Guidance for Medical devices states that: "The goal of EMC is that expected energy in the environment - EMD - will not degrade the performance of a product and that the product will not interfere with another product. This means medical devices should:

1. Account for the expected electromagnetic environment in the design and labeling of the device...

2. Accomplish its intended purpose with degradation of performance in the expected environments, and

3. Not interfere with other devices expected to be used in the same environment..."[32]

In Europe, the concept of "regulatory compliance" through mandated immunity testing adds another layer of protection for victims by assuring that products being sold have demonstrated intrinsic immunity to interference sources likely to be present in their installation environments. For medical equipment in the EU, this means that "EQUIPMENT and SYSTEMS shall not emit ELECTROMAGNETIC DISTURBANCES that could affect radio services, other equipment or the ESSENTIAL PERFORMANCE of other EQUIPMENT and SYSTEMS."[33]

The European standard for EMC in measuring relays and protection equipment (typically used in substations) offers guidance on the protection afforded by limiting maximum electromagnetic emissions when it states: "The object of this Standard is to specify limits and test methods, for measuring relays and protection equipment in relation to

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[28] EN 55022: 2006 (CISPR 22) Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
[29] CISPR 11 (1996) - EN 55011 Limits and Methods of Measurement of Electromagnetic Disturbance Characteristics of Industrial, Scientific and Medical (ISM) Radio Frequency Equipment
[30] CISPR 14 (1993) EN 55011 Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and electric apparatus
[31] CISPR 15 (1992) EN 55015 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
[32] FDA Investigators Guidance - Electromagnetic Compatibility (EMC) January 5, 2000
Guide to Inspections of Electromagnetic Compatibility aspects of Medical Device Quality Systems
[33] IEC 60601-1-2 - 2001: Medical electrical equipment – Part 1-2: General requirements for safety – Collateral standard: Electromagnetic compatibility – Requirements and tests

electromagnetic emissions which may cause interference in other equipment. These emission limits represent electromagnetic compatibility requirements and have been selected to ensure that the disturbances generated by measuring relays and protection equipment, operated normally in substations and power plants, do not exceed a level which could prevent other equipment from operating as intended."[34] As stated before, radio services and other “victim” equipment are primarily protected by the emission limits implemented through National regulations, in this case the CISPR limits.

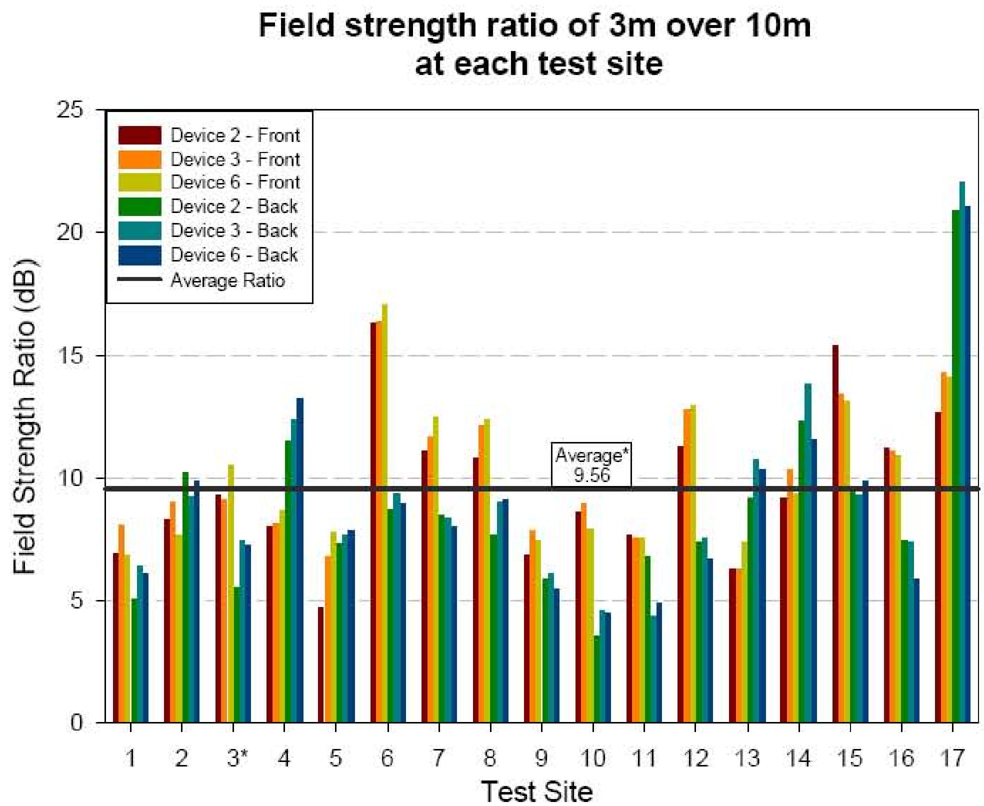
Report: *Canadian Research Centre Measurements of Emissions from 17 Premises with Wiring Carrying BPL Signals*

Since the time of the original Report and Order, there has been a major study, *Canadian Research Centre Measurements of Emissions from 17 Premises with Wiring Carrying BPL Signals*, done on behalf of Industry Canada, making measurements of the emissions of 17 premises with electrical wiring carrying BPL signals. This series of measurements of 17 premises was made using frequency sweeps from 0 to 30 MHz, at multiple distances from the premises, at two points around a building and at multiple times, representing a large number of measurements.

The FCC and other commenters have indicated that such a large number of measurements were necessary to make a determination of the appropriate extrapolation factor to be used below 30 MHz. If such a comprehensive study, specific to BPL and particularly to in-premise BPL were deemed to be insufficient, then the bar would have been set such that no reasonable study could be used to change the 40 dB/decade standard that was temporarily put into the Part 15 rules when they were enacted.

The 101-page CRC study was done to excellent technical standards. It concluded very clearly that the decay of field strength vs distance from premise wiring is very nearly 20 dB/decade. (The study showed an average of -9.56 dB between measurements made at 3 meters and 10 meters distances, a decay of 18.3 dB/decade.)

[34] IEC 60255-26 - 2004-08: Electrical Relays - Part 26: Electromagnetic compatibility requirements for measuring relays and protection equipment



*Test Site 3 is shown on the graph but not taken into consideration for the calculation of the average.

Figure 4-14: Field strength ratio of 3 m over 10 m measurements at each site

Figure 20 -- These data from the CRC report show an average of 18.3 dB/decade extrapolation from premise wiring across the HF frequency range at distances of 3 and 10 meters.

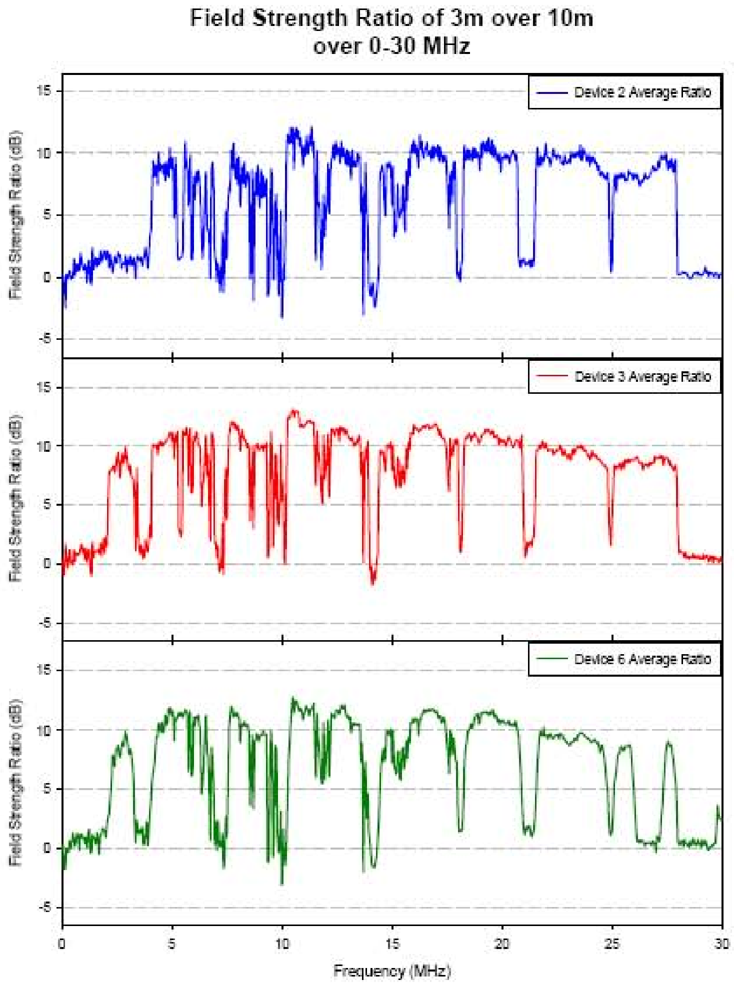


Figure 4-15: Field strength average ratio of 3 m over 10 m measurements over 0-30 MHz for each PLT device

Figure 21 -- These data from the CRC report show how the decay of field strength vs distance varies over frequency. These data represent a decay rate of approximately 20 dB/decade.

March 24, 2009 Draft Version 2.3

7. Field Trial Conclusions

- The extrapolation factor for field strength attenuation over distance is 18.2 dB based on field test results, which is much lower than the 40 dB per decade assumption used by some spectrum authorities.
- Very low emission levels above ambient were observed for the frequencies from 30 to 108 MHz. Test scenarios with more than two PLT devices in a home could result in stronger emission.
- Test results show that emission levels in the operating frequency range can vary over a 20 dB range for any pair of device, depending on the house under test.
- Measured emission level is linearly proportional to the output power of a PLT device (e.g. 10 dB higher output power will result in 10 dB higher emission level).
- Idle mode emission level is not higher than data transfer mode as observed in laboratory conducted tests.
- There are transmission activities during idle mode, resulting in the same interference potential present in data transfer mode.
- Residential buildings connected by overhead electrical lines do not seem to have a significant increase in total emissions due to the potential emission coming from these overhead lines.

Figure 22 -- The CRC study concludes that "(t)he extrapolation factor for field strength over distance is 18.2 dB, ***which is much lower than the 40 dB per decade used by some spectrum authorities****.*

Other Standards Supporting a Change from 40 dB/Decade

In its Comments in the Further Notice of Proposed Rulemaking, ARRL provided the Commission with a number of examples of industry standards and regulations that used factors other than 40 dB/decade to extrapolate vs distance, or that showed a decay of field strength with distance of less than 40 dB/decade. These standards all use some form of a sliding scale where field strength within the reactive near-field region is presumed to decay at 40 dB/decade and the field strength in the far-field region is presumed to decay at 20 dB/decade. These principles, documented in a number of standards, are very much in agreement with the calculations and modeling done by ARRL and by the CRC and other measurements such as those done in Crieff, etc.

Industry standards also support two important principles -- they are designed to find the actual points of maximum emissions from devices being tested, including scanning for height and the standards are focused on setting limits for those maxima at the locations where receivers are apt to be located.

Political vs Technical Goals

A number of BPL-industry commenters indicated that one of the reasons that they reject anything other than a 40 dB/decade extrapolation is that a more stringent requirement would compromise the performance of BPL systems[35]. That is not a *technical* justification for the correct specification of an extrapolation factor or test method. That political position also extends into the technical discussions provided by the BPL industry, with positions that oversimplify near-field and ground-plane considerations, strengthening the position that 40 dB/decade is correct and necessary to the function of BPL products.

In contrast to this position, however, the industry claims that it can reduce its operating power to address or prevent interference. This argument is in sharp contradiction to the statements made in this proceeding numerous times by the BPL industry in which it has emphasized that it can and will control the operating power of BPL systems in operation to mitigate interference. There is a direct correlation between the emissions limits, or extrapolation factor used to asses them and the amount of power a BPL device can use. Every single factor that would apply to any de facto reduction in power due to a change in the way measurements are made or extrapolated applies equally well to a reduction in power to control interference. If power reduction for one reason is possible, power reduction for all reasons is possible. The converse is true, and if this industry alleges that its products cannot function correctly unless the maximum possible operating power is used, then they would also not function correctly if power is reduced to control interference.

[35] For example, *See* Comments of SpiDCOM Technologies in ET Docket No. 04-37 at 2, filed Sept. 23, 2009 (stating that “A reduced extrapolation factor would directly reduce the performance of all BPL devices such that it would be difficult if not impossible to provide a marketable product for Access BPL,” and urging the FCC to “continue to permit use of the 40 dB per decade extrapolation factor under same conditions that have applied for many years.”)

APPENDIX A

MODEL of overhead power line with transformers and grounds

```
CM Cern model w xfmrs and gnd
CM
CM ! Wire # 106  for I srcs, shorted/open TL, and/or loads.
CE
GW 1,101,-250.,0.,10.,-200.,0.,10.,.00635
GW 2,101,-200.,0.,10.,-150.,0.,10.,.00635
GW 3,101,-150.,0.,10.,-100.,0.,10.,.00635
GW 4,101,-100.,0.,10.,-50.,0.,10.,.00635
GW 5,101,-50.,0.,10.,0.,0.,10.,.00635
GW 6,101,0.,0.,10.,50.,0.,10.,.00635
GW 7,101,50.,0.,10.,100.,0.,10.,.00635
GW 8,101,100.,0.,10.,150.,0.,10.,.00635
GW 9,101,150.,0.,10.,200.,0.,10.,.00635
GW 10,101,200.,0.,10.,250.,0.,10.,.00635
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GW 12,101,-200.,1.,10.,-150.,1.,10.,.00635
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GW 14,101,-100.,1.,10.,-50.,1.,10.,.00635
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GW 16,101,0.,1.,10.,50.,1.,10.,.00635
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GW 18,101,100.,1.,10.,150.,1.,10.,.00635
GW 19,101,150.,1.,10.,200.,1.,10.,.00635
GW 20,101,200.,1.,10.,250.,1.,10.,.00635
GW 21,101,-250.,-1.,10.,-200.,-1.,10.,.00635
GW 22,101,-200.,-1.,10.,-150.,-1.,10.,.00635
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GW 27,101,50.,-1.,10.,100.,-1.,10.,.00635
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GW 29,101,150.,-1.,10.,200.,-1.,10.,.00635
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GW 39,101,150.,0.,4.,200.,0.,4.,.00635
GW 40,101,200.,0.,4.,250.,0.,4.,.00635
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GW 42,5,-200.,0.,4.,-200.,0.,0.,.00635
GW 43,5,-150.,0.,4.,-150.,0.,0.,.00635
GW 44,5,-100.,0.,4.,-100.,0.,0.,.00635
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LD 5,15,0,0,5.7471E+7,1.
LD 5,16,0,0,5.7471E+7,1.
LD 5,17,0,0,5.7471E+7,1.
LD 5,18,0,0,5.7471E+7,1.
LD 5,19,0,0,5.7471E+7,1.
LD 5,20,0,0,5.7471E+7,1.
LD 5,21,0,0,5.7471E+7,1.
LD 5,22,0,0,5.7471E+7,1.
LD 5,23,0,0,5.7471E+7,1.
LD 5,24,0,0,5.7471E+7,1.
LD 5,25,0,0,5.7471E+7,1.
LD 5,26,0,0,5.7471E+7,1.
LD 5,27,0,0,5.7471E+7,1.
LD 5,28,0,0,5.7471E+7,1.
LD 5,29,0,0,5.7471E+7,1.
LD 5,30,0,0,5.7471E+7,1.
LD 5,31,0,0,5.7471E+7,1.
LD 5,32,0,0,5.7471E+7,1.
LD 5,33,0,0,5.7471E+7,1.
LD 5,34,0,0,5.7471E+7,1.
LD 5,35,0,0,5.7471E+7,1.
LD 5,36,0,0,5.7471E+7,1.
LD 5,37,0,0,5.7471E+7,1.
LD 5,38,0,0,5.7471E+7,1.
LD 5,39,0,0,5.7471E+7,1.
LD 5,40,0,0,5.7471E+7,1.
LD 5,41,0,0,5.7471E+7,1.
LD 5,42,0,0,5.7471E+7,1.
LD 5,43,0,0,5.7471E+7,1.
LD 5,44,0,0,5.7471E+7,1.
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LD 5,55,0,0,5.7471E+7,1.
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LD 5,57,0,0,5.7471E+7,1.
LD 5,58,0,0,5.7471E+7,1.
LD 5,59,0,0,5.7471E+7,1.
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LD 5,63,0,0,5.7471E+7,1.
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LD 5,67,0,0,5.7471E+7,1.
LD 5,68,0,0,5.7471E+7,1.
LD 5,69,0,0,5.7471E+7,1.
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LD 5,71,0,0,5.7471E+7,1.
LD 5,72,0,0,5.7471E+7,1.
LD 5,73,0,0,5.7471E+7,1.
LD 5,74,0,0,5.7471E+7,1.
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LD 5,87,0,0,5.7471E+7,1.
LD 5,88,0,0,5.7471E+7,1.
LD 5,89,0,0,5.7471E+7,1.
LD 5,90,0,0,5.7471E+7,1.
LD 5,91,0,0,5.7471E+7,1.
LD 5,92,0,0,5.7471E+7,1.
LD 5,93,0,0,5.7471E+7,1.
LD 5,94,0,0,5.7471E+7,1.
LD 5,95,0,0,5.7471E+7,1.
LD 5,96,0,0,5.7471E+7,1.
LD 5,97,0,0,5.7471E+7,1.
LD 5,98,0,0,5.7471E+7,1.
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LD 5,99,0,0,5.7471E+7,1.
LD 5,100,0,0,5.7471E+7,1.
LD 5,101,0,0,5.7471E+7,1.
LD 5,102,0,0,5.7471E+7,1.
LD 5,103,0,0,5.7471E+7,1.
LD 5,104,0,0,5.7471E+7,1.
LD 5,105,0,0,5.7471E+7,1.
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GN 2,0,0,0,13.,.005
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NT 106,1,18,51,0.,0.,0.,1.,0.,0.
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NH 0,501,1,1,-250.,10.,1.,1.,1.,1.
EN
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